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THE HANDHELD PROGRAMMABLE CALCULATOR: AN INTERIM SOLUTION--ETC(U)

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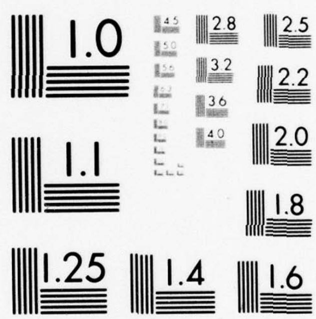

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

STUDY PROJECT

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15 March 1979

LEVEL II

THE HANDHELD PROGRAMMABLE CALCULATOR: AN INTERIM SOLUTION TO DIRECTION FINDING CALCULATIONS IN THE FIELD

by

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US ARMY WAR COLLEGE, CARLISLE BARRACKS, PA 17013

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USAWC MILITARY STUDIES PROGRAM PAPER

THE HANDHELD PROGRAMMABLE CALCULATOR: AN INTERIM SOLUTION TO DIRECTION FINDING CALCULATIONS IN THE FIELD

AN INDIVIDUAL STUDY PROJECT

by

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15 March 1979

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PREFACE

This study was undertaken in order to provide an inexpensive, interim solution to a very pressing problem with regard to direction finding (DF) calculations confronting the divisional Combat Electronic Warfare Intelligence (CEWI) Battalions and separate CEWI Companies. During my tour as Commanding Officer, 522d CEWI Battalion, 2d Armored Division, we were equipped with antiquated electronic warfare equipment designed more for static situations than the modern mobile battlefield which the Armored Division will surely face. As the only TOE authorized CEWI Battalion, the 522d CEWI Battalion was logically selected to test new electronic warfare systems. Unfortunately, the new systems, as configured for our tests, did not meet tactical requirements for survivability, reliability, and maintainability. Pending further modifications before major systems procurement, many units will continue to face the dilemma of antiquated equipment which predates on-board integrated data processing equipment. Without data processing assistance the tactical units will continue to make triangulation calculations manually utilizing the time consuming and inaccurate technique of a map, protractor, magnetic board, and strings with magnets, to determine the location of enemy emitters.

When afforded the time and access to the data processing expertise of Captain Schonewetter, this problem became solvable. It is the aim of this study to show that an effective interim solution does not have to be large, expensive, air-conditioned, nor too complicated for the

analyst to learn in one day. It must be emphasized from the start that this is an interim solution. The handheld calculator is slow; the calculation time to determine the eight-digit coordinates of three intersecting lines is two-to-three minutes, four intersecting lines is three-to-four minutes, and five intersecting lines is four-to-five minutes. A well-trained analyst can determine the location that fast with the string method, but not with accuracy or a mathematical probability of accuracy. Also, the analyst must have the map and all the support materials associated with it while the calculator method requires none of the bulky support elements, not even the map, though it may be desirable.

The data processing package (Texas Instruments Programmable 59 Calculator with Surveying Module = $250; Print/Security Cradle PC-100A Electronic Printer = $145) is inexpensive enough to be expendable, thus reducing the burden of maintenance backup. It is also our hope that the design of future data processing support packages for tactical units will be influenced by this practical and inexpensive solution.

CHAPTER 1

The Electronic Direction Finding Problem at Division Level

Introduction

Based on my past experience as the G2 and later as the Commander, 522d CEWI Battalion, 2d Armored Division:

> the Army does not have a survivable tactical ground-based electronic direction finding capability at division level, nor are we likely to achieve that capability in the near future.

The above statement may come as a shock to some and an embarrassment to others as it is often assumed that tactical ground-based electronic direction finding equipment is available, because much of the current literature dealing with Electronic Warfare does not define systems limitations nor distinguish between ground-based and airborne systems, nor specify from which echelon control will be exercised. Figures 1 and 2 are from the US Army Electronic Warfare Concept, dated 6 Mar 78. The charts are designed to portray OPTIONS, as is clearly stated.

COMM NET BY ECHELON	FIRST ECHELON						SECOND ECHELON		FRONT
DISTANCE FROM FEBA (KM)	0-3	3-6	6-9	9-15	15-20	20-30	30-50	50-100	100-UP
COMMAND AND CONTROL	JAM	JAM/ LOCATE	JAM/ LOCATE	INTCP/ LOCATE	INTCP/ LOCATE	INTCP/ LOCATE	INTCP	INTCP	INTCP
ROCKET & ARTILLERY AND ASSOCIATED TA	JAM	JAM/ LOCATE	JAM/ LOCATE	LOCATE/ JAM	LOCATE	LOCATE	LOCATE	LOCATE	LOCATE
SURFACE/SURFACE MISSILES				LOCATE	LOCATE	LOCATE	LOCATE	LOCATE	LOCATE
AIR DEFENSE	JAM/ LOCATE	JAM/ LOCATE	JAM/ LOCATE	JAM/ LOCATE	LOCATE	LOCATE	LOCATE	LOCATE	LOCATE
INTELLIGENCE	JAM	JAM	JAM	JAM/ LOCATE	INTCP	INTCP	INTCP	INTCP	INTCP
JAMMERS	LOCATE	LOCATE	LOCATE	LOCATE					
ENGINEERS	LOCATE	LOCATE	LOCATE	LOCATE	LOCATE	INTCP	INTCP	INTCP	INTCP
CAS COMMUNICATIONS	JAM	JAM	JAM	JAM					
COMBAT SERVICE SUPPORT	JAM	JAM	JAM	JAM	INTCP	INTCP	INTCP	INTCP	INTCP

FIGURE 1. Example of electronic options against hostile communications while in the attack.

NOTE: These options will change little during contact in either the attack or the defense. The major changes arise during preparations.

NON COMMUNICATIONS TARGETS								
DISTANCE FROM FEBA (KM)	0-3	3-6	6-9	9-15	15-20	20-30	30-50	50-UP
SURVEILLANCE	JAM	JAM	JAM					
AIR DEFENSE	LOCATE/ JAM	LOCATE/ JAM	LOCATE/ JAM	LOCATE/ JAM	LOCATE/ JAM	LOCATE/ JAM	PRIMARY AF RESP	PRIMARY AF RESP
AAA	LOCATE	LOCATE	LOCATE	LOCATE	LOCATE	LOCATE	PRIMARY AF RESP	PRIMARY AF RESP
COUNTERMORTAR COUNTERBATTERY	LOCATE/ JAM	LOCATE/ JAM	LOCATE/ JAM	LOCATE/ JAM				
NONCOMM JAMMERS	LOCATE	LOCATE	LOCATE	LOCATE	LOCATE			

FIGURE 2. Example of electronic attack options against noncommunications systems.

However, they, like many other ambiguous charts and statements, suggest capabilities which simply do not exist at the order of magnitude implied by the options matrix. My intent is not to criticize the EW Concept Manual, but to point out a possible source of misperception to the unsuspecting reader.

The direction finding (DF) problem is not unlike that facing the tank gunner in combat; they must both operate in proximity to the enemy to be effective, and there will be more than enough targets to engage. Success for the tank gunner and the DF operator will be dependent on rapid identification of targets, engagement, and moving on to the next target.

The tactical ground-based electronic direction finding equipment must have characteristics similar to other combat vehicles operating on or near the FEBA. DF vehicles must be hardened, mobile, technically sound, and capable of operating on internal power for extended periods. Additionally, DF equipment must have integrated data processing components to perform the trigonometric calculations, display the target coordinates and the mathematical probability of accuracy. These capabilities are not currently available in tactical ground-based DF equipment, nor are they being developed in a tactically survivable package.

The obvious question is: "why not?." My experience with DF equipment currently found in the CEWI Battalion and with the field test of one future system, indicates our design engineers have felt bigger was better without understanding the fatal consequences of large

immobile items of equipment on/or near the FEBA. At the same time we, the recipients of the end product, have failed to properly forewarn contract designers of the inability of the divisional maintenance system to repair in a timely manner, overly sophisticated, low-density items of equipment.

Our equipment is becoming so sophisticated with excessive technology that if we are not careful to configure the equipment <u>first</u> to satisfy the tactical commanders needs, we will end up with equipment that cannot be operated, maintained nor repaired by our soldiers in combat. Those characteristics which <u>must</u> be met to satisfy the tactical commanders needs are:

1) capable of mission accomplishment in a survivable configuration,

2) as mobile as the force which it is to support, to include the ability to operate on the move,

3) maintainable by organic divisional maintenance assets, or designed to utilize expendable components which are readily available at the battalion maintenance level.

We should not buy equipment designed for the division battle area which is so complex that the expertise of Technical Representatives of the manufacturer is required. Tech Reps will not be in the division battle area. Soldiers will be the only ones operating, maintaining and repairing equipment on the division battlefield, and if they cannot operate, maintain and repair it quickly, there is no need to buy the equipment under the ultimately false, though well intended, justification of combat need.

The Organizational and Procedural Problems

Today at the CEWI Battalion level any DF effort must be provisionally organized, as the TOE does not provide an organizational structure nor dedicate all the equipment necessary for DF operations. Direction-finding operations require multiple lines of bearing to the enemy emitter in order to compute the target location. By definition two lines of bearing are a "cut" and three lines of bearing are a "fix." The current CEWI Battalion TOE does not provide enough equipment in the Collection and Jamming Platoon for a concurrent DF fix (three lines of bearing taken at the same time). Therefore, to organize a DF operation requires task organizing the DF assets from at least two platoons, as well as providing the task organization with a secure "Flash Net," which includes secure radios and CEOI-related materials. A Flash Net is required in order that a control authority (Platoon Leader or Battalion Operations Center) can orchestrate the DF sites to the right frequency at precisely the right time. See Figure 3. This is necessary to insure that all DF sites are plotting lines of bearing to the targetted emitter (and not one of its out-stations by accident), and to insure maximum utilization of this scarce resource. The DF site, like the tank crew, must rapidly identify, engage, and move on to the next target.

Present and projected equipment, of both the DF site and Control Authority, lacks adequate mobility, survivability, and technical simplicity. This study presents an interim solution by which one of the

current problems of direction finding, the trigonometric calculations, can easily be solved by use of the TI-59 programmable calculator. This interim solution requires no increase in TOE personnel nor Service School training requirement. The twelve ounce calculator or a series of them might reasonably be considered as an acceptable substitute for the vehicle-mounted, air conditioned, delicate computer which is projected as a component of a future tactical system.

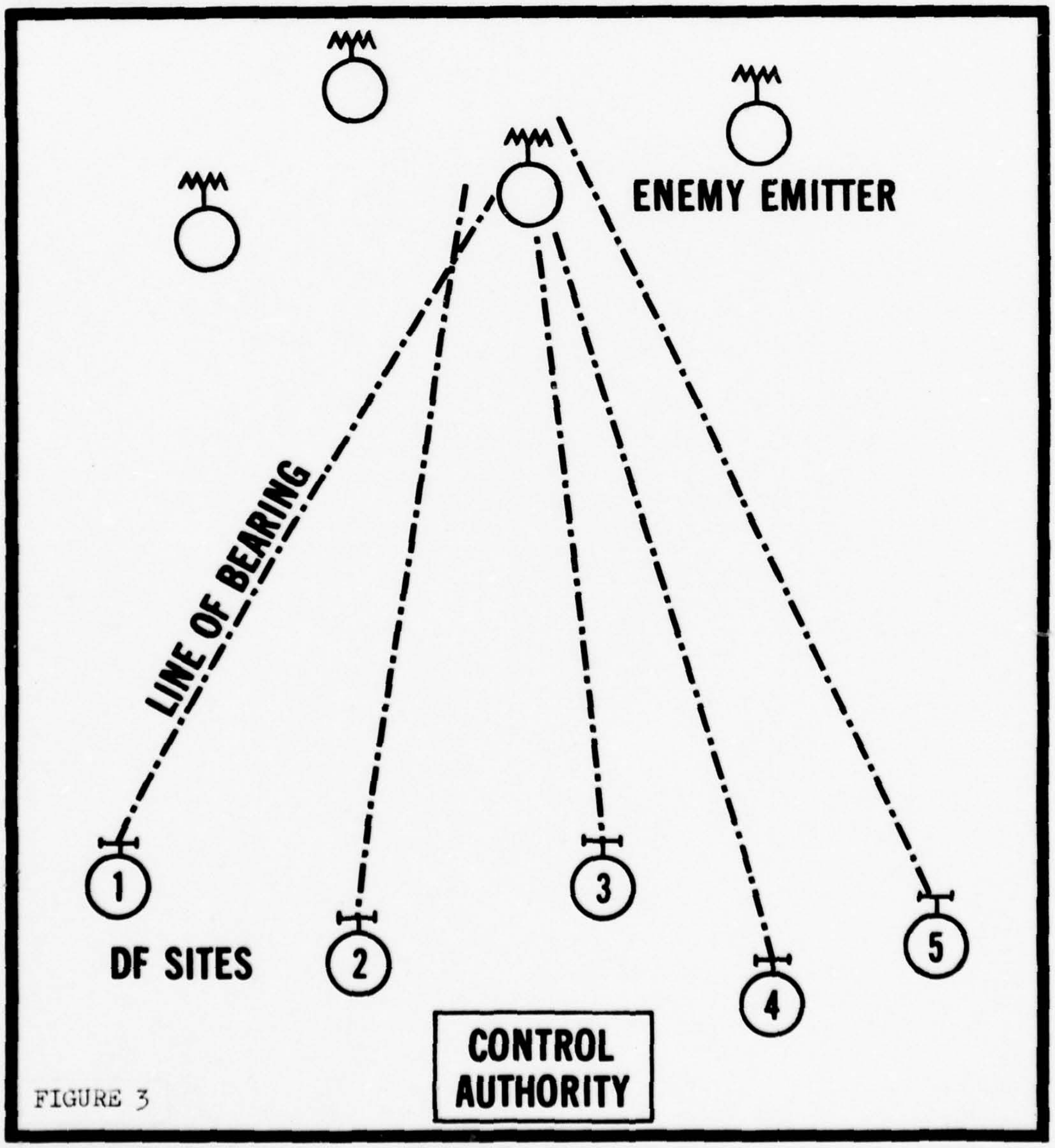


FIGURE 3

The intermediate results of the DF operation are lines of bearing (azimuths) to an enemy emitter from widely separated DF sites whose exact locations are known to the control authority. The lines of bearing are called to the control authority from the DF sites, and the control authority determines the enemy emitter location by using a protractor and pieces of string on a map board. The enemy emitter is assumed to be at the point of intersection of the strings. This technique is slow and accuracy is accidental. Weather, darkness--almost anything--will detract from the accuracy of this method. The location of the enemy emitter may also be determined by the use of trigonometry, however, only a few analysts are able to understand and retain the techniques of pure mathematical determination beyond the exam at the service school.

The final result of the DF operation should be an accurate location of an enemy emitter which can be added to the Commander's knowledge of the enemy's disposition and will hopefully lead to the destruction of the enemy by friendly action. This is rarely accomplished due to a combination of all the factors mentioned above, but most damaging to credibility is the absence of a measure of accuracy in conjunction with an eight-digit coordinate from which artillery can base a fire mission. The purpose of this study is to provide a means by which this can be accomplished in order to bridge the period from the current generation of equipment to future systems which will have data processing equipment integrated.

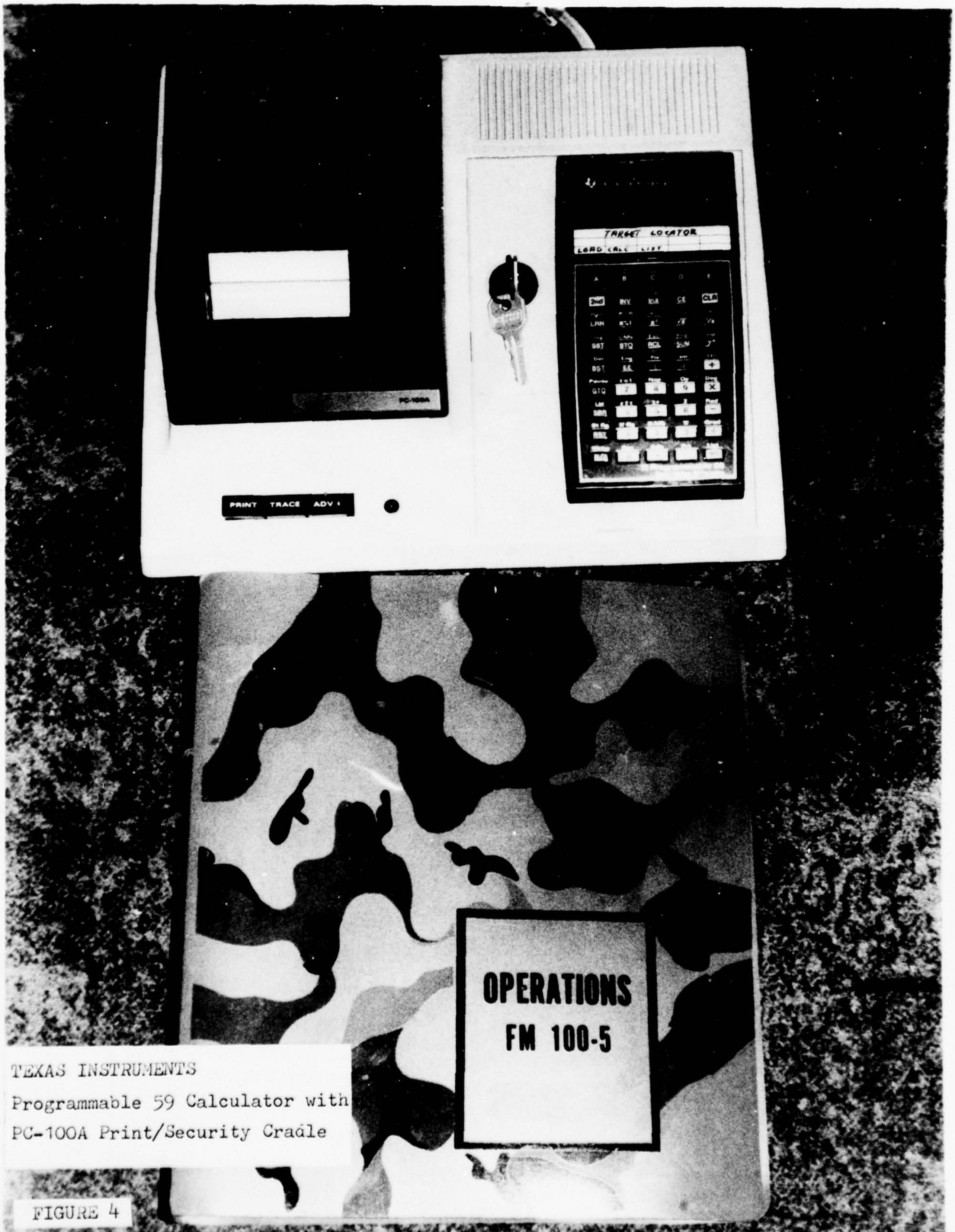
A PROPOSED INTERIM SOLUTION

It must be emphasized from the start that this proposed interim solution does not correct any of the inherent inaccuracies of the current generation of DF equipment. The proposed interim solution will address only the data processing deficiency. This problem can be partially corrected with the inexpensive Texas Instruments handheld programmable calculator, TI-59, with the "Surveying" solid state software module, and the Texas Instruments Print / Security Cradle PC-100A Electronic Printer as shown in Figure 4.

The TI-59 can perform all the calculations with or without the printer. The obvious advantage is a written record of all the essential information when utilizing the printer.

The data required for input to the TI-59 for calculation of the enemy emitter is recorded on a worksheet (Figure 5). A blank worksheet is provided as part of this study for local reproduction as an authorized form.

The program for the TI-59, which is provided in its entirety in the subsequent chapters of this study, provides for an input of not less than two and not more than five lines of bearing from known DF sites. The program will provide a display on the calculator of an eight-digit coordinate which represents the location of the enemy emitter. The two-digit prefix, which is separated by a decimal point from the eight-digit coordinate, represents the map sheet on which the coordinates of the enemy emitter fall. One hundred (10x10) 100,000



TEXAS INSTRUMENTS
Programmable 59 Calculator with
PC-100A Print/Security Cradle

FIGURE 4

SINGLE TARGET
DIRECTION FINDING WORKSHEET
INPUT

MAP - LETTERS ⟷ NUMBERS CONVERSION

EAST - WEST									
0	1	2	3	4	5	6	7	8	9

NORTH - SOUTH									
0	1	2	3	4	5	6	7	8	9

O P # 1	TARGET READING #			1	2	3	4	5	6	7	8	9	10
	AZMUTH TO TARGET												REG # 18
		MAP LETTERS		MAP NUMBERS		COORDINATE							REG # 19
O P # 2	TARGET READING #			1	2	3	4	5	6	7	8	9	10
	AZMUTH TO TARGET												REG # 20
		MAP LETTERS		MAP NUMBERS		COORDINATE							REG # 21
O P # 3	TARGET READING #			1	2	3	4	5	6	7	8	9	10
	AZMUTH TO TARGET												REG # 22
		MAP LETTERS		MAP NUMBERS		COORDINATE							REG # 23
O P # 4	TARGET READING #			1	2	3	4	5	6	7	8	9	10
	AZMUTH TO TARGET												REG # 24
		MAP LETTERS		MAP NUMBERS		COORDINATE							REG # 25
O P # 5	TARGET READING #			1	2	3	4	5	6	7	8	9	10
	AZMUTH TO TARGET												REG # 26
		MAP LETTERS		MAP NUMBERS		COORDINATE							REG # 27

RESULTS FROM CALCULATOR

TARGET READING #	MAP LETTERS		MAP NUMBERS		COORDINATE							STANDARD DEVIATION		
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
			REG # 39									REG # 38		

FIGURE 5

meter square grid zones, which are identified by two alphabetical letters, can be accomodated in the area of operations on the worksheet and in the program. Another display will give a number which represents the mathematical probability of accuracy with zero being perfect and anything over 150 suspect.

AN OPERATIONAL CONCEPT

The control authority (Platoon Leader) would establish a baseline with sufficient distance to allow for accurate calculations to the enemy emitters. Ideally, the baseline should be equal to or greater than the expected distance to the enemy emitter. The control authority must be positioned so as to have good communications with all DF sites via the Flash Net. An alternate means of communications other than the Flash Net is also desirable.

The control authority (Platoon Leader) may be backed up by the Battalion Operations Center, which is also known as the Technical Control and Analysis Center (TCAC). In a mobile situation, the platoon leader and his analyst could use the TI-59 without the printer as described in Chapter 4. The TI-59 can be operated on rechargable batteries, however, the calculations required for the DF problem drain the power rapidly. The recharge unit can easily be adapted to provide power from the Platoon Leader's vehicle. The Battalion Operations Center which has available a constant power supply would utilize the

TI-59 with printer as described in Chapter 3. Permanent records on each enemy emitter obtained from the printer would have obvious analytical uses.

Prior to deployment the Platoon Leader would determine the anticipated area of operations and record the map sheet identification letters on the worksheet. Once the baseline and Flash Net were established, the Platoon Leader would then record the location of the DF sites on the worksheet and enter them into the calculator. As the operation progressed and the DF sites began providing lines of bearing (azimuths) to the enemy emitter, the appropriate entries would be made on the worksheet and entered into the calculator. Since a number of lines of bearing will be taken by the DF site before moving, once the site locations are entered into the calculator they will remain in memory until altered. This speeds the operation since only new azimuths are required for calculation. The results are passed to the next higher authority and/or direct to artillery, depending on the nature of the DF operation.

Utilizing the TI-59 could, with practice, enable the Platoon Leader or Battalion Operations Center to analyze the lines of bearing being sent by the DF sites to determine if any one of the DF sites has an obvious equipment malfunction.

A current disadvantage to the system proposed in this study is the calculator utilizes the "Surveying" module and inputs a new program into it via program strips. The calculator must be re-programmed each time it loses power either by choice or chance. The re-programming takes only 30-45 seconds, but a special module with the DF program printed in

it would eliminate this deficiency. A test of an artillery-related module for the TI-59 is currently being conducted at Ft. Hood. This study has been sent to TRADOC Combined Arms Test Activity (TCATA) for consideration for future test modules.

Chapter 2

TI59 Target Locator System
Program Storage Guide

INTRODUCTION

There are two (2) ways to enter this program into the TI59 programmable calculator. The first method consists of manually entering the program via the calculator keyboard. The other method utilizes the magnetic cards and is discussed in great detail in the user's guide for this system. If you do not possess magnetic cards with the program already on them, you will need to enter the program using the manual method and then store it on the magnetic cards. Once this process has been completed the program may be entered from the cards, which because of the length of the program is the preferred method. The process of entering the program and storing it on cards is summarized throughout the rest of this guide.

P R O G R A M   E N T R Y

In order to enter this program into the calculator you are strongly encouraged to familiarize yourself with the "programming considerations" chapter of the Personal Programming Manual (the owner's manual) supplied by Texas Instruments along with the calculator.

Program Listing

The first step will be to examine the program listing of the TI59 Target Locator System on pages 18 to 24. As you look at this listing you will see three (3) columns of information. The first column contains the three (3) digit program location. The second column contains the two (2) digit key code for the contents of that memory location. The third column contains the key symbol for that memory location. The key code and the key symbol both represent a key on the keyboard. The key code uses its first digit to specify which row the key is in and the second digit represents the specific key, counting from top to bottom and left to right. This is explained in detail in the TI-59 Owner's Manual.

Program Entry

Now that you have carefully read the TI Owner's Manual you are ready to enter the program.

A. Power on the TI59 calculator.

action   Power on TI59 calculator.

result   0   appears on calculator display.

FIGURE 2. Example of electronic attack options against noncommunications systems.

B. Position program memory.

action Press 4 , 2nd , Op , 1 , and then 7 .

result 639.39 appears on the display.

C. Enter the 640 program storage locations as listed on pages 18 to 24.

action Press CLR , 2nd , CP , LRN .

result 000 00 appears on the display.

* * * * * * * * * *

action Enter keystroke.

result Next memory location number and 00 will be displayed. Repeat action until program is entered.

* * * * * * * * * *

action Press LRN .

result 0 appears on the display.

D. Checking and correcting entries.

action Press GTO , ### , where ### is a three (3) digit number that is the memory location you would like to check.

result 0 appears on the display

* * * * * * * * * *

action Press LRN .

result Three (3) digit memory location and two (2) digit key code

of the contents of that location will appear.

* * * * * * * * * *

action If the key code is incorrect, enter the correct keystroke.

result Next memory location number and its key code is displayed.

* * * * * * * * * *

action Press SST or BST .

result The memory location after or before the current memory location will be displayed.

* * * * * * * * * *

action Press LRN .

result 0 appears on the display.

It cannot be overemphasized that the material presented above is a gross overview of the material in the owner's manual. In order to successfully enter a program you must be familiar with the information presented in the manual.

PROGRAM STORAGE LOCATION LISTING

COLUMN

①	②	③
000	76	LBL
001	11	A
002	01	1
003	08	8
004	42	STO
005	01	01
006	01	1
007	00	0
008	42	STO
009	02	02
010	76	LBL
011	89	π
012	43	RCL
013	01	01
014	94	+/-
015	32	X:T
016	43	RCL
017	01	01
018	94	+/-
019	91	R/S
020	67	EQ
021	00	00
022	27	27
023	72	ST*
024	01	01
025	76	LBL
026	90	LST
027	69	OP
028	21	21
029	97	DSZ
030	02	02
031	00	00
032	12	12
033	00	0
034	92	RTN
035	76	LBL
036	29	CP
037	53	(
038	09	9
039	00	0
040	32	X:T
041	73	RC*
042	00	00
043	22	INV
044	67	EQ
045	00	00
046	62	62
047	53	(
048	32	X:T
049	85	+
050	08	8
051	94	+/-
052	22	INV
053	28	LOG
054	54	)
055	72	ST*
056	00	00
057	61	GTO
058	00	00
059	86	86
060	76	LBL
061	36	PGM
062	32	X:T
063	02	2
064	07	7
065	00	0
066	67	EQ
067	00	00
068	74	74
069	61	GTO
070	00	00
071	86	86
072	76	LBL
073	37	P/R
074	53	(
075	32	X:T
076	85	+
077	07	7
078	94	+/-
079	22	INV
080	28	LOG
081	54	)
082	72	ST*
083	00	00
084	76	LBL
085	87	IFF
086	54	)
087	92	RTN

```
088  76  LBL
089  86  STF
090  53  (
091  53  (
092  43  RCL
093  11   11
094  55  ÷
095  04  4
096  22  INV
097  28  LOG
098  54  )
099  53  (
100  42  STO
101  09   09
102  59  INT
103  65  ×
104  01  1
105  00  0
106  54  )
107  42  STO
108  14   14
109  43  RCL
110  09   09
111  22  INV
112  59  INT
113  44  SUM
114  14   14
115  53  (
116  43  RCL
117  10   10
118  55  ÷
119  04  4
120  22  INV
121  28  LOG
122  54  )
123  42  STO
124  09   09
125  59  INT
126  44  SUM
127  14   14
128  53  (
129  43  RCL
130  09   09
131  22  INV
132  59  INT
133  55  ÷
```

```
134  04  4
135  22  INV
136  28  LOG
137  54  )
138  44  SUM
139  14   14
140  43  RCL
141  14   14
142  54  )
143  92  RTN
144  76  LBL
145  39  COS
146  53  (
147  00  0
148  32  X:T
149  53  (
150  73  RC*
151  00   00
152  85  +
153  93  .
154  05  5
155  54  )
156  59  INT
157  77   GE
158  01   01
159  66   66
160  00  0
161  61  GTO
162  01   01
163  79   79
164  76  LBL
165  30  TAN
166  32  X:T
167  09  9
168  09  9
169  09  9
170  09  9
171  09  9
172  22  INV
173  77   GE
174  01   01
175  79   79
176  32  X:T
177  76  LBL
178  47  CMS
179  72  ST*
```

180	00	00
181	54	)
182	92	RTN
183	76	LBL
184	60	DEG
185	53	(
186	53	(
187	53	(
188	53	(
189	73	RC*
190	00	00
191	55	÷
192	01	1
193	00	0
194	54	)
195	59	INT
196	65	×
197	04	4
198	22	INV
199	28	LOG
200	54	)
201	42	STO
202	09	09
203	53	(
204	73	RC*
205	00	00
206	22	INV
207	59	INT
208	65	×
209	04	4
210	22	INV
211	28	LOG
212	54	)
213	59	INT
214	44	SUM
215	09	09
216	43	RCL
217	09	09
218	32	X:T
219	53	(
220	53	(
221	53	(
222	73	RC*
223	00	00
224	55	÷
225	01	1
226	00	0
227	54	)
228	22	INV
229	59	INT
230	65	×
231	01	1
232	00	0
233	54	)
234	59	INT
235	65	×
236	04	4
237	22	INV
238	28	LOG
239	54	)
240	42	STO
241	09	09
242	53	(
243	73	RC*
244	00	00
245	65	×
246	04	4
247	22	INV
248	28	LOG
249	54	)
250	53	(
251	22	INV
252	59	INT
253	65	×
254	04	4
255	22	INV
256	28	LOG
257	54	)
258	44	SUM
259	09	09
260	54	)
261	43	RCL
262	09	09
263	54	)
264	92	RTN
265	76	LBL
266	50	I×I
267	53	(
268	01	1
269	42	STO
270	06	06
271	05	5

272	42	STO
273	08	08
274	87	IFF
275	02	02
276	02	02
277	86	86
278	03	3
279	42	STO
280	06	06
281	07	7
282	42	STO
283	08	08
284	76	LBL
285	68	NOP
286	00	0
287	32	X:T
288	73	RC*
289	00	00
290	77	GE
291	03	03
292	02	02
293	76	LBL
294	57	ENG
295	86	STF
296	01	01
297	61	GTO
298	03	03
299	27	27
300	76	LBL
301	69	OP
302	71	SBR
303	01	01
304	85	85
305	72	ST*
306	06	06
307	01	1
308	44	SUM
309	06	06
310	32	X:T
311	72	ST*
312	06	06
313	69	OP
314	30	30
315	00	0
316	32	X:T
317	73	RC*

318	00	00
319	22	INV
320	77	GE
321	02	02
322	95	95
323	72	ST*
324	08	08
325	76	LBL
326	58	FIX
327	54	)
328	92	RTN
329	76	LBL
330	12	B
331	53	(
332	02	2
333	07	7
334	42	STO
335	17	17
336	02	2
337	05	5
338	42	STO
339	16	16
340	03	3
341	07	7
342	42	STO
343	15	15
344	76	LBL
345	48	EXC
346	22	INV
347	86	STF
348	01	01
349	86	STF
350	02	02
351	22	INV
352	86	STF
353	03	03
354	43	RCL
355	17	17
356	42	STO
357	00	00
358	71	SBR
359	02	02
360	67	67
361	22	INV
362	87	IFF
363	01	01

364	03	03
365	77	77
366	86	STF
367	03	03
368	76	LBL
369	38	SIN
370	01	1
371	94	+/-
372	61	GTO
373	04	04
374	61	61
375	76	LBL
376	66	PAU
377	05	5
378	42	STO
379	00	00
380	71	SBR
381	00	00
382	37	37
383	22	INV
384	86	STF
385	02	02
386	76	LBL
387	49	PRD
388	22	INV
389	86	STF
390	01	01
391	43	RCL
392	16	16
393	42	STO
394	00	00
395	71	SBR
396	02	02
397	67	67
398	87	IFF
399	01	01
400	03	03
401	70	70
402	07	7
403	42	STO
404	00	00
405	71	SBR
406	00	00
407	37	37
408	01	1
409	32	X:T
410	53	(
411	43	RCL
412	05	05
413	75	-
414	43	RCL
415	07	07
416	54	)
417	50	I×I
418	22	INV
419	77	GE
420	03	03
421	70	70
422	53	(
423	24	CE
424	75	-
425	01	1
426	08	8
427	00	0
428	54	)
429	50	I×I
430	22	INV
431	77	GE
432	03	03
433	70	70
434	01	1
435	42	STO
436	06	06
437	42	STO
438	08	08
439	36	PGM
440	16	16
441	15	E
442	01	1
443	00	0
444	42	STO
445	00	00
446	71	SBR
447	01	01
448	46	46
449	01	1
450	01	1
451	42	STO
452	00	00
453	71	SBR
454	01	01
455	46	46

456	71	SBR
457	00	00
458	90	90
459	76	LBL
460	70	RAD
461	72	ST*
462	15	15
463	01	1
464	94	+/-
465	44	SUM
466	15	15
467	02	2
468	94	+/-
469	44	SUM
470	16	16
471	01	1
472	09	9
473	32	X↕T
474	43	RCL
475	16	16
476	22	INV
477	77	GE
478	04	04
479	89	89
480	87	IFF
481	03	03
482	03	03
483	70	70
484	61	GTO
485	03	03
486	88	88
487	76	LBL
488	23	LNX
489	02	2
490	94	+/-
491	44	SUM
492	17	17
493	43	RCL
494	17	17
495	67	EQ
496	05	05
497	10	10
498	53	(
499	24	CE
500	75	-
501	02	2

502	54	)
503	42	STO
504	16	16
505	61	GTO
506	03	03
507	46	46
508	76	LBL
509	67	EQ
510	36	PGM
511	01	01
512	71	SBR
513	25	CLR
514	01	1
515	01	1
516	42	STO
517	07	07
518	00	0
519	42	STO
520	12	12
521	76	LBL
522	77	GE
523	22	INV
524	97	DSZ
525	07	07
526	05	05
527	61	61
528	00	0
529	32	X↕T
530	53	(
531	43	RCL
532	07	07
533	85	+
534	02	2
535	07	7
536	54	)
537	42	STO
538	08	08
539	73	RC*
540	08	08
541	22	INV
542	77	GE
543	05	05
544	23	23
545	01	1
546	44	SUM
547	12	12

```
548  43  RCL
549  08   08
550  42  STO
551  00   00
552  71  SBR
553  01   01
554  85   85
555  78  Σ+
556  61  GTO
557  05   05
558  23   23
559  76  LBL
560  78  Σ+
561  53   (
562  79   x̄
563  85   +
564  93   .
565  05   5
566  54   )
567  59  INT
568  42  STO
569  10   10
570  53   (
571  32  X⇄T
572  85   +
573  93   .
574  05   5
575  54   )
576  59  INT
577  42  STO
578  11   11
579  71  SBR
580  00   00
581  90   90
582  42  STO
583  39   39
584  02   2
585  32  X⇄T
586  43  RCL
587  12   12
588  77   GE
589  05   05
590  98   98
591  01   1
592  94  +/-
593  61  GTO
594  06   06
595  15   15
596  76  LBL
597  79   x̄
598  53   (
599  53   (
600  22  INV
601  79   x̄
602  33  X²
603  85   +
604  32  X⇄T
605  33  X²
606  54   )
607  34  √X
608  85   +
609  93   .
610  05   5
611  54   )
612  59  INT
613  76  LBL
614  80  GRD
615  42  STO
616  38   38
617  43  RCL
618  39   39
619  54   )
620  92  RTN
621  76  LBL
622  13   C
623  53   (
624  01   1
625  08   8
626  22  INV
627  90  LST
628  43  RCL
629  39   39
630  32  X⇄T
631  43  RCL
632  38   38
633  54   )
634  92  RTN
635  00   0
636  00   0
637  00   0
638  00   0
639  00   0
```

P R O G R A M   S T O R A G E

Now that the system is loaded into the calculator it must be stored on magnetic cards. Once again the owner's manual must be referred to for complete understanding of this process. The steps shown below summarize the actions necessary to produce the cards.

action   Press CLR , 1 , 2nd , Write , and then enter card 1 into the slot on the right side of the calculator.

result   1 appears on the display (if a blinking number appears repeat the action).

* * * * * * * * * *

action   Press CLR , 2 , 2nd , Write , and then enter card 2 into the slot on the right side of the calculator.

result   2 appears on the display (if a blinking number appears repeat the action).

* * * * * * * * * *

action   Press CLR , 3 , 2nd , Write , and then enter card 3 into the slot on the right side of the calculator.

result   3 appears on the display (if a blinking number appears repeat the action).

* * * * * * * * * *

action	Press CLR , 4 , 2nd , Write , and then enter card 4 into the slot on the right side of the calculator.
result	4 appears on the display (if a blinking numbers appears repeat the action).

The program has now been stored on magnetic cards and you are ready to use the system user's guides.

Chapter 3

TI59 Target Locator System
User's Guide With Printer

INTRODUCTION

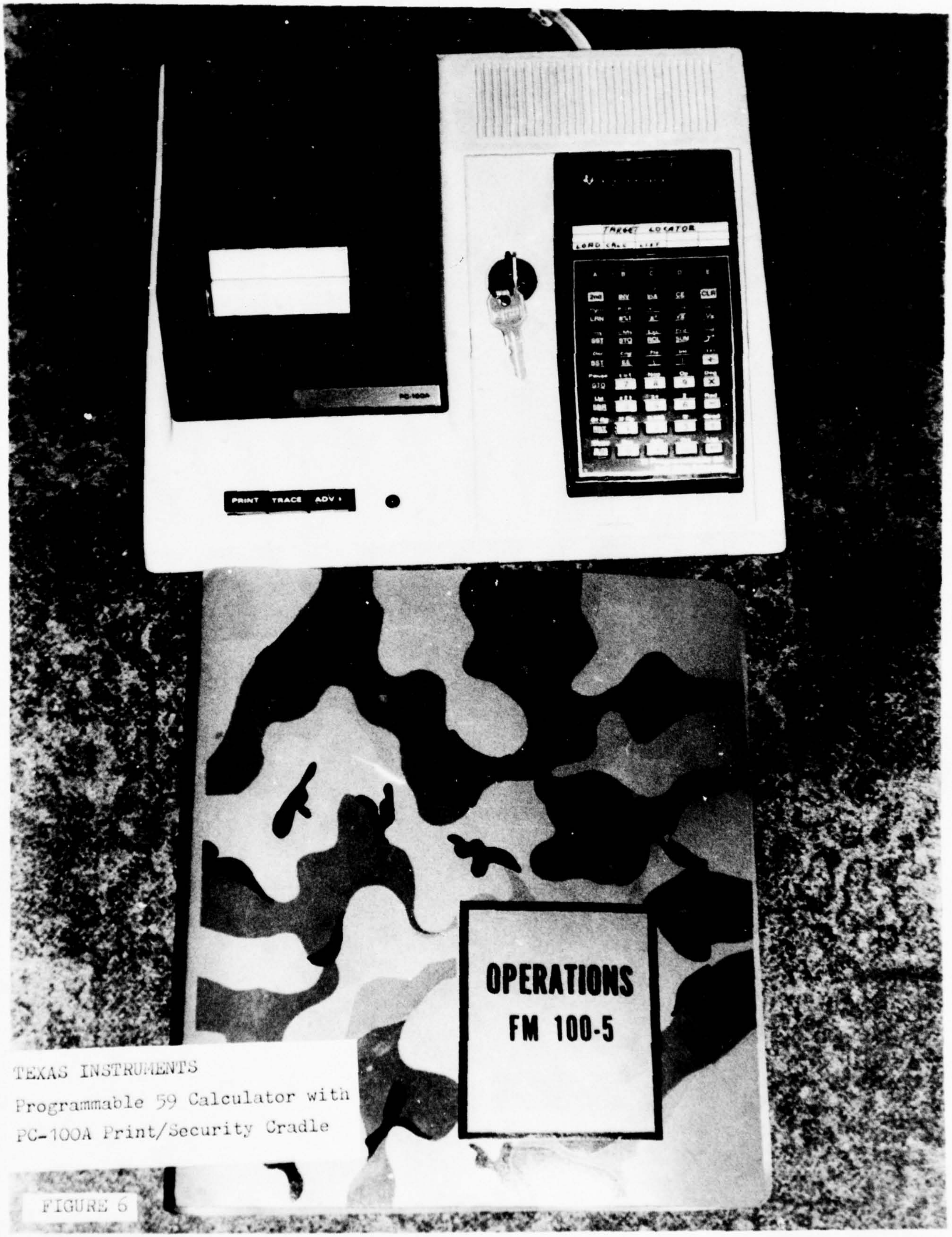
This user's guide will enable you to effectively utilize the TI59 Target Locator System.

Assumptions about you and the equipment, which are critical to the successful operation of the system, are listed below:

1. The Texas Instruments TI Programmable 59 calculator with the Texas instruments Print/Security Cradle PC-100A (electronic printer) as shown in Figure 6 is being used.

2. The TI programmable calculator has the "SURVEYING" Solid State Software Module mounted in the module compartment on the lower back of the calculator.

3. You have thoroughly familiarized yourself with the operation of the calculator and printer through the use of Texas Instruments manuals and actual use of the equipment.



TEXAS INSTRUMENTS
Programmable 59 Calculator with
PC-100A Print/Security Cradle

FIGURE 6

4. The Target Locator worksheet, designed specifically for this system, will be used in addition to the calculator and printer.

5. There will always be no fewer than two (2) OP locations (by coordinates) and azimuths nor more than five (5) OP locations and azimuths for each calculation attempted by the system.

6. You are aware that when the area of operations crosses a six (6) by eight (8) or six (6) by twelve (12) degree zone boundary that differences due to the Universal Transverse Mercator (UTM) Grid system will cause various amounts of error to occur. The magnitude of this error will be a function of the latitude of the area of operations. This system, due to a shortage of programmable memory, makes no allowances for a zone boundary crossing. TM 5-241-2 may be used to accomplish this manually. Future expansion of the memory available in the TI-59 may allow for these calculations to be accomplished in the program as is currently done in TACFIRE.

7. The program does not consider differences in altitude between the DF sites and the enemy emitter. This must be accomplished by Artillery prior to fire missions.

This guide is composed of four (4) major sections. The first section describes the worksheet and how it is used. The second section covers the loading of the program into the calculator from magnetic cards. The third section details the use of the calculator program to calculate an approximate target location. The last section delineates the forty (40) data registers in the calculator used by the program.

USE OF THE WORKSHEET

I. Pre-program worksheet posting.

A. Map selection. Select extreme south-west 100,000-meter square to be used. This square must be the south-west corner of a 1000 km square that encompasses the expected area of operations.

B. Fill in EAST WEST chart. See Figure 7. Place the first 100,000-meter square identification letter of the selected square in the block below the zero (0) in the chart labeled "EAST-WEST", then fill in the rest of the chart with the next nine (9) identification letters (e.g. if T were placed in row zero (0) then use U, V, W, X, Y, Z, A, B, and C to fill in the other rows).

C. Fill in NORTH SOUTH chart. See Figure 7. Place the second 100,000-meter square identification letter of the selected map in the block below the zero (0) in the chart labeled "NORTH-SOUTH", then fill in the rest of the chart with the next nine (9) identification letters (e.g. if L was placed in row zero (0) then use M, N, P, Q, R, S, T, U, and V to fill in the other rows).

SINGLE TARGET
DIRECTION FINDING WORKSHEET
INPUT

MAP - LETTERS ⟷ NUMBERS CONVERSION

EAST - WEST

0	1	2	3	4	5	6	7	8	9
T	U	V	W	X	Y	Z	A	B	C

NORTH - SOUTH

0	1	2	3	4	5	6	7	8	9
L	M	N	P	Ø	R	S	T	U	V

OP												
OP # 1	TARGET READING #	1	2	3	4	5	6	7	8	9	10	REG # 18
	AZMUTH TO TARGET											
	MAP LETTERS	MAP NUMBERS	COORDINATE									REG # 19
OP # 2	TARGET READING #	1	2	3	4	5	6	7	8	9	10	REG # 20
	AZMUTH TO TARGET											
	MAP LETTERS	MAP NUMBERS	COORDINATE									REG # 21
OP # 3	TARGET READING #	1	2	3	4	5	6	7	8	9	10	REG # 22
	AZMUTH TO TARGET											
	MAP LETTERS	MAP NUMBERS	COORDINATE									REG # 23
OP # 4	TARGET READING #	1	2	3	4	5	6	7	8	9	10	REG # 24
	AZMUTH TO TARGET											
	MAP LETTERS	MAP NUMBERS	COORDINATE									REG # 25
OP # 5	TARGET READING #	1	2	3	4	5	6	7	8	9	10	REG # 26
	AZMUTH TO TARGET											
	MAP LETTERS	MAP NUMBERS	COORDINATE									REG # 27

RESULTS FROM CALCULATOR

TARGET READING #	MAP LETTERS	MAP NUMBERS	COORDINATE	STANDARD DEVIATION
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
		REG # 39		REG # 38

FIGURE 7

D. Post the Observation Post coordinates. See Figure 8. For each Observation Post (OP), in any order, place the appropriate 100,000-meter identification letters in the blocks titled "MAP LETTERS" and the eight (8) digit coordinate in the blocks titled "COORDINATE" (e.g. YN04006195, YP70052595, XN40020598, XN82022798, and YN38059195).

SINGLE TARGET
DIRECTION FINDING WORKSHEET
INPUT

MAP - LETTERS ⟷ NUMBERS CONVERSION

EAST - WEST											NORTH - SOUTH									
0	1	2	3	4	5	6	7	8	9		0	1	2	3	4	5	6	7	8	9
T	U	V	W	X	Y	Z	A	B	C		L	M	N	P	Q	R	S	T	U	V

O P # 1	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG # 18
	AZMUTH TO TARGET													
		MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 19
		Y	N			0	4	0	0	6	1	9	5	
O P # 2	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG # 20
	AZMUTH TO TARGET													
		MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 21
		Y	P			7	0	0	5	2	5	9	5	
O P # 3	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG # 22
	AZMUTH TO TARGET													
		MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 23
		X	N			4	0	0	2	0	5	9	8	
O P # 4	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG # 24
	AZMUTH TO TARGET													
		MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 25
		X	N			8	2	0	2	2	7	9	8	
O P # 5	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG # 26
	AZMUTH TO TARGET													
		MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 27
		Y	N			3	8	0	5	9	1	9	5	

RESULTS FROM CALCULATOR

TARGET READING #	MAP LETTERS		MAP NUMBERS		COORDINATE							STANDARD DEVIATION		
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
			REG # 39									REG # 38		

FIGURE 8

E. Post the MAP NUMBERS. See Figure 9. Using the "EAST-WEST" and "NORTH-SOUTH" charts, convert the MAP LETTERS into MAP NUMBERS and place these numbers in the blocks titled "MAP NUMBERS" (e.g. YN: Y, using the "EAST-WEST" chart, becomes 5; N, using the "NORTH-SOUTH" chart, becomes 2).

SINGLE TARGET
DIRECTION FINDING WORKSHEET
INPUT

MAP - LETTERS ←→ NUMBERS CONVERSION

EAST - WEST	0	1	2	3	4	5	6	7	8	9
	T	U	V	W	X	Y	Z	A	B	C

NORTH - SOUTH	0	1	2	3	4	5	6	7	8	9
	L	M	N	P	Q	R	S	T	U	V

OP													REG #
OP # 1	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 18
	AZMUTH TO TARGET												
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 19
	Y	N	5	2	0	4	0	0	6	1	9	5	
OP # 2	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 20
	AZMUTH TO TARGET												
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 21
	Y	P	5	3	7	0	0	5	2	5	9	5	
OP # 3	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 22
	AZMUTH TO TARGET												
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 23
	X	N	4	2	4	0	0	2	0	5	9	8	
OP # 4	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 24
	AZMUTH TO TARGET												
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 25
	X	N	4	2	8	2	0	2	2	7	9	8	
OP # 5	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 26
	AZMUTH TO TARGET												
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 27
	Y	N	5	2	3	8	0	5	9	1	9	5	

RESULTS FROM CALCULATOR

TARGET READING #	MAP LETTERS		MAP NUMBERS		COORDINATE								STANDARD DEVIATION		
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
			REG # 39										REG # 38		

FIGURE 9

F. Post the OP azimuths. See Figure 10. Gather the azimuths from the OP's and enter them in the "AZIMUTH TO TARGET" row in the next available "TARGET READING #" column (e.g. OP # 1 azimuth is 330 degrees, enter 330 in the appropriate block).

SINGLE TARGET
DIRECTION FINDING WORKSHEET
INPUT

MAP - LETTERS ←→ NUMBERS CONVERSION

	EAST - WEST										NORTH - SOUTH									
	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
	T	U	V	W	X	Y	Z	A	B	C	L	M	N	P	Q	R	S	T	U	V

O P													
# 1	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 18
	AZMUTH TO TARGET		330										
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 19
	Y	N	5	2	0	4	0	0	6	1	9	5	
# 2	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 20
	AZMUTH TO TARGET		283										
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 21
	Y	P	5	3	7	0	0	5	2	5	9	5	
# 3	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 22
	AZMUTH TO TARGET		5										
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 23
	X	N	4	2	4	0	0	2	0	5	9	8	
# 4	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 24
	AZMUTH TO TARGET		347										
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 25
	X	N	4	2	8	2	0	2	2	7	9	8	
# 5	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 26
	AZMUTH TO TARGET		306										
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 27
	Y	N	5	2	3	8	0	5	9	1	9	5	

RESULTS FROM CALCULATOR

TARGET READING #	MAP LETTERS		MAP NUMBERS		COORDINATE								STANDARD DEVIATION		
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
			REG # 39										REG # 38		

FIGURE 10

II. Posting calculated results from the program.

A. Posting the calculated target location. See Figure 11. Enter the calculated target location in the "RESULTS FROM CALCULATOR" chart in the columns labeled "MAP NUMBERS" and "COORDINATE." Using the two (2) 100,000-meter square identification charts convert the MAP NUMBERS into MAP LETTERS and enter them in the column labeled "MAP LETTERS" (e.g. 43: 4, using the "EAST WEST" chart, becomes X; 3, using the "NORTH SOUTH" chart, becomes P). Note that leading and trailing zeroes (0) are not printed. Therefore, a coordinate like 5.378554 will be treated as 05.37855400. Remember, there will always be two (2) digits to the left of the decimal point and eight (8) digits to the right in a valid coordinate.

B. Posting the standard deviation of the calculated target location. See Figure 11. Enter the standard deviation on the worksheet from the calculator display or from register 38 on the paper tape listing in the columns titled "STANDARD DEVIATION" (Note that when only one target location is calculated, the standard deviation will be shown as -1. , which is done to show that there is no valid standard deviation). The accuracy of the azimuths becomes more questionable as the standard deviation goes up.

SINGLE TARGET DIRECTION FINDING WORKSHEET

INPUT

MAP - LETTERS ⟷ NUMBERS CONVERSION

EAST - WEST									
0	1	2	3	4	5	6	7	8	9
T	U	V	W	X	Y	Z	A	B	C

NORTH - SOUTH									
0	1	2	3	4	5	6	7	8	9
L	M	N	P	Ø	R	S	T	U	V

OP # 1	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 18
	AZMUTH TO TARGET		330										
		MAP LETTERS	MAP NUMBERS		COORDINATE								REG # 19
		Y N	5	2	0	4	0	0	6	1	9	5	
OP # 2	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 20
	AZMUTH TO TARGET		283										
		MAP LETTERS	MAP NUMBERS		COORDINATE								REG # 21
		Y P	5	3	7	0	0	5	2	5	9	5	
OP # 3	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 22
	AZMUTH TO TARGET		5										
		MAP LETTERS	MAP NUMBERS		COORDINATE								REG # 23
		X N	4	2	4	0	0	2	0	5	9	8	
OP # 4	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 24
	AZMUTH TO TARGET		347										
		MAP LETTERS	MAP NUMBERS		COORDINATE								REG # 25
		X N	4	2	8	2	0	2	2	7	9	8	
OP # 5	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 26
	AZMUTH TO TARGET		306										
		MAP LETTERS	MAP NUMBERS		COORDINATE								REG # 27
		Y N	5	2	3	8	0	5	9	1	9	5	

RESULTS FROM CALCULATOR

TARGET READING #	MAP LETTERS	MAP NUMBERS		COORDINATE								STANDARD DEVIATION		
1	X P	4	3	5	2	7	3	5	2	8	4	2	5	9
2														
3														
4														
5														
6														
7														
8														
9														
10														
		REG # 39										REG # 38		

FIGURE 11

P R O G R A M   S E T   U P

A. Power on TI59 Calculator.

action Power on TI59 calculator.

result 0 appears on caculator display.

B. Load program into calculator.

action Press 4 , 2nd , Op , 1 , and then 7 .

result 639.39 appears on the display.

* * * * * * * * * *

action Press CLR , INV , 2nd , Write , and then enter card 1 into the slot on the right of the TI59.

result 1 appears on the display (if blinking 1 or 0 repeat the action).

* * * * * * * * * *

action Press CLR , INV , 2nd , Write , and then enter card 2 into the slot on the right of the TI59.

result 2 appears on the display (if blinking 2 or 0 repeat the action).

* * * * * * * * * *

action Press CLR , INV , 2nd , Write , and then enter card 3 into the slot on the right of the TI59.

result 3 appears on the display (if blinking 3 or 0 repeat the action).

* * * * * * * * * *

action Press CLR , INV , 2nd , Write , and then enter card 4 into the slot on the right of the TI59.

result 4 appears on the display (if blinking 4 or 0 repeat the action).

P R O G R A M U S E

A. Initial data input

action Press A .

result -18. displayed on the calculator (18 represents the data register used to hold azimuth number 1. See the right column of the "INPUT" portion of the worksheet or the last section of this guide for the register numbers of the azimuths.

* * * * * * * * * *

action Enter azimuth for OP number 1 (use a positive number between 0.0 and 360.0) and then press the R/S button. If there is no azimuth for that OP, press 1 , then press +/- and then press R/S .

result OP number 1 azimuth entered, -19. displayed on the calculator.

* * * * * * * * * *

action Enter coordinate for OP number 1 (use a positive number between 00.00000000 and 99.99999999) and then press R/S . If there is no coordinate for that OP, press 1 , then press +/- and then press R/S (note that coordinate register numbers are listed in the far right column of the "INPUT" portion of the worksheet and in the last section of this guide).

result OP number 1 coordinate entered, -20. displayed on the calculator.

* * * * * * * * * *

action Using the procedures outlined in the two (2) previous "actions", enter the remaining four (4) OP azimuths and coordinates.

result All initial azimuths and coordinates are entered and a zero (0) will appear on the calculator display.

B. Later data input. After initial data input to the system, the OP coordinates will be relatively stable. Changes will encompass azimuth refinements, new target acquisition azimuths, and possibly an occasional OP coordinate change. Use of the system during this phase is covered below.

action Press A .

result -18. displayed on calculator.

* * * * * * * * * *

action If the register number displayed on the calculator is one that is to be changed, enter the new value, and then press R/S . If there is no azimuth or coordinate to be entered (e.g. no sighting from an OP, or dropping a particular OP during its relocation, etc.), press 1 , then press +/- , and then press R/S . If the current register is not to be changed, simply press R/S . After the last change has been entered and the R/S pressed, press CLR .

result 0 is displayed on the calculator and all data registers contain new data.

C. Target calculation.

action Press C .

result A paper tape listing of data registers 18 through 39 will be listed on the printer. Check registers 18, 20, 22, 24, and 26 for the OP azimuths and registers 19, 21, 23, 25, and 27 for the OP coordinates (remember that leading and trailing zeroes (0) will not be printed, so treat a coordinate like 3.7654789 as 03.76547890). See Figure 12 for a sample listing.

330.	18
52.04006195	19
283.	20
53.70052595	21
5.	22
42.40020598	23
347.	24
42.82022798	25
306.	26
52.38059195	27
43.51215339	28
43.52695082	29
43.528853	30
43.54314802	31
43.53175293	32
43.52965386	33
43.49565624	34
43.54555261	35
43.52955378	36
43.52985376	37
259.	38
43.52735284	39

FIGURE 12

* * * * * * * * * * *

action	If an error on one or more azimuths or coordinates has occurred, press A . When the display contains the register number of an error, then enter the correct value and press R/S . If the register number is not that of an error, press R/S and move to the next register. Repeat this process until all errors are corrected. After the last error has been corrected and the R/S has been pressed, press CLR . Now go back to the previous action, press C , and recheck the registers.

result	All azimuths and coordinates have been entered.

* * * * * * * * * * *

action	Press B (this step may take as long as 5.5 minutes).

result	The calculated target location will be displayed on the calculator (remember that leading and trailing zeroes (0) are not printed, so treat a coordinate like 7.975313 as 07.97531300). While the calculation is taking place the printer will periodically print the north coordinate of the intermediate target locations. This is a function of the "SURVEYING" Solid State Software Module that is being used by the system, and cannot be avoided.

* * * * * * * * * * *

action Press C .

result The printer will list registers 18 through 39. Registers 18 through 27 contain initial data, 28 through 37 contain calculated target locations (-1 indicates that no calculation was performed), 38 contains the standard deviation of the calculated target location, and 39 contains the approximate target location (remember that leading and trailing zeroes (0) will not be printed, so treat a coordinate like 6.2468543 as 06.24685430). The standard deviation will be displayed on the calculator.

* * * * * * * * * * *

action To return the calculated target coordinate to the calculator display, press X><T .

result Calculated target location displayed on the calculator.

D A T A   R E G I S T E R S

This system uses forty (40) of the available data registers on the TI59 calculator. The registers and their contents are listed below:

REGISTER	CONTENTS
00 - 17	working storage
18	azimuth for OP number 1
19	coordinate for OP number 1
20	azimuth for OP number 2
21	coordinate for OP number 2
22	azimuth for OP number 3
23	coordinate for OP number 3
24	azimuth for OP number 4
25	coordinate for OP number 4
26	azimuth for OP number 5
27	coordinate for OP number 5
28	calculated target location using OP 2 & 1
29	calculated target location using OP 3 & 1
30	calculated target location using OP 3 & 2
31	calculated target location using OP 4 & 1
32	calculated target location using OP 4 & 2
33	calculated target location using OP 4 & 3
34	calculated target location using OP 5 & 1
35	calculated target location using OP 5 & 2
36	calculated target location using OP 5 & 3

37	calculated target location using OP 5 & 4
38	standard deviation of calculated target location
39	calculated target location

Chapter 4

T I 5 9 T a r g e t L o c a t o r S y s t e m
U s e r ' s G u i d e W i t h o u t P r i n t e r

I N T R O D U C T I O N

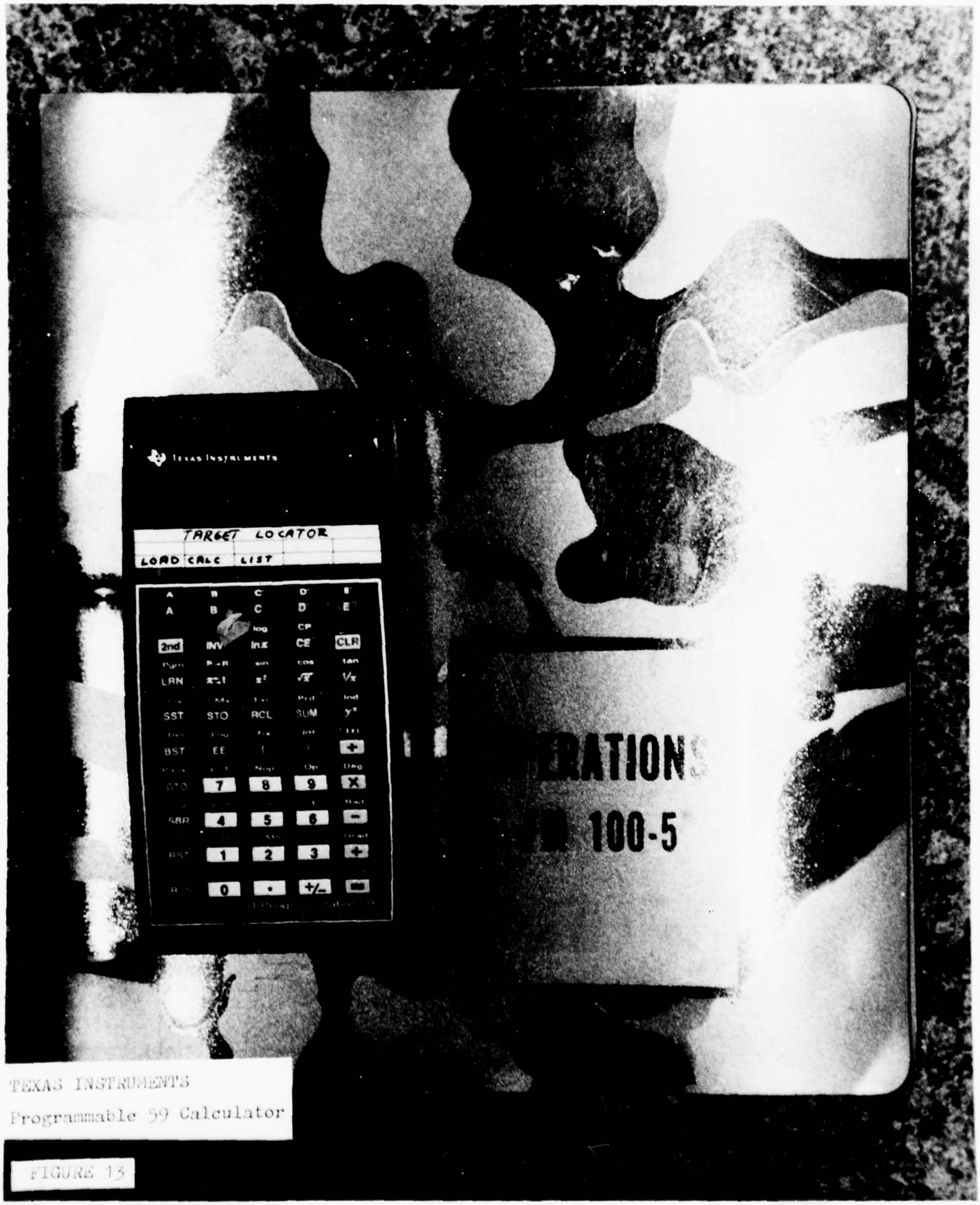
This user's guide will enable you to effectively utilize the TI59 Target Locator System.

Assumptions about you and the calculator, which are critical to the successful operation of the system, are listed below:

1. The Texas Instruments TI Programmable 59 calculator as shown in Figure 13 is being used.

2. The TI Programmable calculator has the "SURVEYING" Solid State Software Module mounted in the module compartment on the lower back of the calculator.

3. You have thoroughly familiarized yourself with the operation of the calculator through the use of Texas Instruments manuals and actual use of the calculator.



TEXAS INSTRUMENTS
Programmable 59 Calculator

FIGURE 13

4. The Target Locator worksheet, designed specifically for this system, will be used in addition to the calculator and printer.

5. There will always be not less than two (2) OP coordinates and azimuths nor more than five (5) OP coordinates and azimuths for each calculation attempted by the system.

6. You are aware that when the area of operations crosses a six (6) by eight (8) or six (6) by twelve (12) degree zone boundary that differences due to the Universal Transverse Mercator (UTM) Grid system will cause various amounts of error to occur. The magnitude of this error will be a function of the latitude of the area of operations. This system makes no allowances for a zone boundary crossing.

This guide is composed of four (4) major sections. The first section describes the worksheet and how it is used. The second section covers the loading of the program into the calculator from magnetic cards. The third section details the use of the calculator program to calculate an approximate target location. The last section delineates the forty (40) data registers in the calculator used by the program.

U S E   O F   T H E   W O R K S H E E T

I. Pre-program worksheet posting.

A. Map selection. Select extreme south-west 100,000-meter square to be used. This square must be the south-west corner of a 1000 km square that encompasses the expected area of operations.

B. Fill in EAST WEST chart. See Figure 14. Place the first 100,000-meter square identification letter of the selected square in the block below the zero (0) in the chart labeled "EAST-WEST", then fill in the rest of the chart with the next nine (9) identification letters (e.g. if T were placed in row zero (0) then use U, V, W, X, Y, Z, A, B, and C to fill in the other rows).

C. Fill in NORTH SOUTH chart. See Figure 14. Place the second 100,000-meter square identification letter of the selected map in the block below the zero (0) in the chart labeled "NORTH-SOUTH", then fill in the rest of the chart with the next nine (9) identification letters (e.g. if L was placed in row zero (0) then use M, N, P, Q, R, S, T, U, and V to fill in the other rows).

SINGLE TARGET
DIRECTION FINDING WORKSHEET
INPUT

MAP - LETTERS ⟷ NUMBERS CONVERSION

EAST - WEST										NORTH - SOUTH									
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
T	U	V	W	X	Y	Z	A	B	C	L	M	N	P	Ø	R	S	T	U	V

O P # 1	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 18	
	AZMUTH TO TARGET													
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 19	
O P # 2	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 20	
	AZMUTH TO TARGET													
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 21	
O P # 3	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 22	
	AZMUTH TO TARGET													
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 23	
O P # 4	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 24	
	AZMUTH TO TARGET													
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 25	
O P # 5	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 26	
	AZMUTH TO TARGET													
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 27	

RESULTS FROM CALCULATOR

TARGET READING #	MAP LETTERS	MAP NUMBERS	COORDINATE	STANDARD DEVIATION
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
			REG # 39	REG # 38

FIGURE 14

D. Post the Observation Post coordinates. See Figure 15. For each Observation Post (OP), in any order, place the appropriate 100,000-meter identification letters in the blocks titled "MAP LETTERS" and the eight (8) digit coordinate in the blocks titled "COORDINATE" (e.g. YN04006195, YP70052595, XN40020598, XN82022798, and YN38059195).

SINGLE TARGET
DIRECTION FINDING WORKSHEET
INPUT

MAP - LETTERS ⟷ NUMBERS CONVERSION

EAST - WEST

0	1	2	3	4	5	6	7	8	9
T	U	V	W	X	Y	Z	A	B	C

NORTH - SOUTH

0	1	2	3	4	5	6	7	8	9
L	M	N	P	Ø	R	S	T	U	V

OP														
OP # 1	TARGET READING #		1	2	3	4	5	6	7	8	9	10		REG # 18
	AZMUTH TO TARGET													
	MAP LETTERS		MAP NUMBERS		COORDINATE									REG # 19
	Y	N			0	4	0	0	6	1	9	5		
OP # 2	TARGET READING #		1	2	3	4	5	6	7	8	9	10		REG # 20
	AZMUTH TO TARGET													
	MAP LETTERS		MAP NUMBERS		COORDINATE									REG # 21
	Y	P			7	0	0	5	2	5	9	5		
OP # 3	TARGET READING #		1	2	3	4	5	6	7	8	9	10		REG # 22
	AZMUTH TO TARGET													
	MAP LETTERS		MAP NUMBERS		COORDINATE									REG # 23
	X	N			4	0	0	2	0	5	9	8		
OP # 4	TARGET READING #		1	2	3	4	5	6	7	8	9	10		REG # 24
	AZMUTH TO TARGET													
	MAP LETTERS		MAP NUMBERS		COORDINATE									REG # 26
	X	N			8	2	0	2	2	7	9	8		
OP # 5	TARGET READING #		1	2	3	4	5	6	7	8	9	10		REG # 26
	AZMUTH TO TARGET													
	MAP LETTERS		MAP NUMBERS		COORDINATE									REG # 27
	Y	N			3	8	0	5	9	1	9	5		

RESULTS FROM CALCULATOR

TARGET READING #	MAP LETTERS	MAP NUMBERS	COORDINATE	STANDARD DEVIATION
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
			REG # 39	REG # 38

FIGURE 15

E. Post the MAP NUMBERS. See Figure 16. Using the "EAST-WEST" and "NORTH-SOUTH" charts, convert the MAP LETTERS into MAP NUMBERS and place these numbers in the blocks titled "MAP NUMBERS" (e.g. YN: Y, using the "EAST-WEST" chart, becomes 5; N, using the "NORTH-SOUTH" chart, *becomes 2*).

SINGLE TARGET
DIRECTION FINDING WORKSHEET
INPUT

MAP - LETTERS ⟷ NUMBERS CONVERSION

EAST - WEST

0	1	2	3	4	5	6	7	8	9
T	U	V	W	X	Y	Z	A	B	C

NORTH - SOUTH

0	1	2	3	4	5	6	7	8	9
L	M	N	P	Q	R	S	T	U	V

O P # 1	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG #
	AZMUTH TO TARGET													18
		MAP LETTERS		MAP NUMBERS		COORDINATE								REG #
		Y	N	5	2	0	4	0	0	6	1	9	5	19
O P # 2	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG #
	AZMUTH TO TARGET													20
		MAP LETTERS		MAP NUMBERS		COORDINATE								REG #
		Y	P	5	3	7	0	0	5	2	5	9	5	21
O P # 3	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG #
	AZMUTH TO TARGET													22
		MAP LETTERS		MAP NUMBERS		COORDINATE								REG #
		X	N	4	2	4	0	0	2	0	5	9	8	23
O P # 4	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG #
	AZMUTH TO TARGET													24
		MAP LETTERS		MAP NUMBERS		COORDINATE								REG #
		X	N	4	2	8	2	0	2	2	7	9	8	25
O P # 5	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG #
	AZMUTH TO TARGET													26
		MAP LETTERS		MAP NUMBERS		COORDINATE								REG #
		Y	N	5	2	3	8	0	5	9	1	9	5	27

RESULTS FROM CALCULATOR

TARGET READING #	MAP LETTERS		MAP NUMBERS		COORDINATE								STANDARD DEVIATION		
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
			REG # 39										REG # 38		

FIGURE 16

F. Post the OP azimuths. See Figure 17. Gather the azimuths from the OP's and enter them in the "AZIMUTH TO TARGET" row in the next available "TARGET READING #" column (e.g. OP # 1 azimuth is 330 degrees, enter 330 in the appropriate block).

SINGLE TARGET
DIRECTION FINDING WORKSHEET
INPUT

MAP - LETTERS ⟷ NUMBERS CONVERSION

EAST - WEST										NORTH - SOUTH									
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
T	U	V	W	X	Y	Z	A	B	C	L	M	N	P	Ø	R	S	T	U	V

OP													REG #
O P # 1	TARGET READING #		1	2	3	4	5	6	7	8	9	10	
	AZMUTH TO TARGET		330										REG # 18
	MAP LETTERS		MAP NUMBERS		COORDINATE								
	Y	N	5	2	0	4	0	0	6	1	9	5	REG # 19
O P # 2	TARGET READING #		1	2	3	4	5	6	7	8	9	10	
	AZMUTH TO TARGET		283										REG # 20
	MAP LETTERS		MAP NUMBERS		COORDINATE								
	Y	P	5	3	7	0	0	5	2	5	9	5	REG # 21
O P # 3	TARGET READING #		1	2	3	4	5	6	7	8	9	10	
	AZMUTH TO TARGET		5										REG # 22
	MAP LETTERS		MAP NUMBERS		COORDINATE								
	X	N	4	2	4	0	0	2	0	5	9	8	REG # 23
O P # 4	TARGET READING #		1	2	3	4	5	6	7	8	9	10	
	AZMUTH TO TARGET		347										REG # 24
	MAP LETTERS		MAP NUMBERS		COORDINATE								
	X	N	4	2	8	2	0	2	2	7	9	8	REG # 25
O P # 5	TARGET READING #		1	2	3	4	5	6	7	8	9	10	
	AZMUTH TO TARGET		306										REG # 26
	MAP LETTERS		MAP NUMBERS		COORDINATE								
	Y	N	5	2	3	8	0	5	9	1	9	5	REG # 27

RESULTS FROM CALCULATOR

TARGET READING #	MAP LETTERS		MAP NUMBERS		COORDINATE								STANDARD DEVIATION		
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
			REG # 39										REG # 38		

FIGURE 17

II. Posting calculated results from the program.

A. Posting the calculated target location. See Figure 18. Enter the calculated target location in the "RESULTS FROM CALCULATOR" chart in the columns labeled "MAP NUMBERS" and "COORDINATE." Using the two (2) 100,000-meter square identification charts convert the MAP NUMBERS into MAP LETTERS and enter them in the column labeled "MAP LETTERS" (e.g. 43: 4, using the "EAST WEST" chart, becomes X; 3, using the "NORTH SOUTH" chart, becomes P). Note that leading and trailing zeroes (0) are not printed. Therefore, a coordinate like 5.378554 will be treated as 05.37855400. Remember, there will always be two (2) digits to the left of the decimal point and eight (8) digits to the right in a valid coordinate.

B. Posting the standard deviation of the calculated target location. See Figure 18. Enter the standard deviation on the worksheet from the calculator display or from register 38 in the columns titled "STANDARD DEVIATION" (Note that when only one target location is calculated, the standard deviation will be shown as -1. , which is done to show that there is no valid standard deviation). The accuracy of the azimuths becomes more questionable as the standard deviation goes up.

SINGLE TARGET
DIRECTION FINDING WORKSHEET
INPUT

MAP - LETTERS ⟷ NUMBERS CONVERSION

EAST - WEST

0	1	2	3	4	5	6	7	8	9
T	U	V	W	X	Y	Z	A	B	C

NORTH - SOUTH

0	1	2	3	4	5	6	7	8	9
L	M	N	P	Ø	R	S	T	U	V

OP														REG #
OP # 1	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG # 18
	AZMUTH TO TARGET			330										
		MAP LETTERS ↓		MAP NUMBERS ↓		↓ COORDINATE							↓	REG # 19
		Y	N	5	2	0	4	0	0	6	1	9	5	
OP # 2	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG # 20
	AZMUTH TO TARGET			283										
		MAP LETTERS ↓		MAP NUMBERS ↓		↓ COORDINATE							↓	REG # 21
		Y	P	5	3	7	0	0	5	2	5	9	5	
OP # 3	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG # 22
	AZMUTH TO TARGET			5										
		MAP LETTERS ↓		MAP NUMBERS ↓		↓ COORDINATE							↓	REG # 23
		X	N	4	2	4	0	0	2	0	5	9	8	
OP # 4	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG # 24
	AZMUTH TO TARGET			347										
		MAP LETTERS ↓		MAP NUMBERS ↓		↓ COORDINATE							↓	REG # 25
		X	N	4	2	8	2	0	2	2	7	9	8	
OP # 5	TARGET READING #			1	2	3	4	5	6	7	8	9	10	REG # 26
	AZMUTH TO TARGET			306										
		MAP LETTERS ↓		MAP NUMBERS ↓		↓ COORDINATE							↓	REG # 27
		Y	N	5	2	3	8	0	5	9	1	9	5	

RESULTS FROM CALCULATOR

TARGET READING # ↓	MAP LETTERS ↓		MAP NUMBERS ↓		↓ COORDINATE							↓	↓ STANDARD DEVIATION ↓		
1	X	P	4	3	5	2	7	3	5	2	8	4	2	5	9
2															
3															
4															
5															
6															
7															
8															
9															
10															
			REG # 39										REG # 38		

FIGURE 18

P R O G R A M   S E T   U P

A. Power on TI59 Calculator.

action Power on TI59 calculator.

result 0 appears on caculator display.

B. Load program into calculator.

action Press 4 , 2nd , Op , 1 , and then 7 .

result 639.39 appears on the display.

* * * * * * * * * *

action Press CLR , INV , 2nd , Write , and then enter card 1 into the slot on the right of the TI59.

result 1 appears on the display (if blinking 1 or 0 repeat the action).

* * * * * * * * * *

action Press CLR , INV , 2nd , Write , and then enter card 2 into the slot on the right of the TI59.

result 2 appears on the display (if blinking 2 or 0 repeat the action).

* * * * * * * * * *

action Press CLR , INV , 2nd , Write , and then enter card 3 into the slot on the right of the TI59.

result 3 appears on the display (if blinking 3 or 0 repeat the action).

* * * * * * * * * *

action Press CLR , INV , 2nd , Write , and then enter card 4 into the slot on the right of the TI59.

result 4 appears on the display (if blinking 4 or 0 repeat the action).

P R O G R A M   U S E

A. Initial data input

action Press A .

result -18. displayed on the calculator (18 represents the data register used to hold azimuth number 1. See the right column of the "INPUT" portion of the worksheet or the last section of this guide for the register numbers of the azimuths.

* * * * * * * * * * *

action Enter azimuth for OP number 1 (use a positive number between 0.0 and 360.0) and then press the R/S button. If there is no azimuth for that OP, press 1 , then press +/- and then press R/S .

result OP number 1 azimuth entered, -19. displayed on the calculator.

* * * * * * * * * * *

action Enter coordinate for OP number 1 (use a positive number between 00.00000000 and 99.99999999) and then press R/S . If there is no coordinate for that OP, press 1 , then press +/- and then press R/S (note that coordinate register numbers are listed in the far right column of the "INPUT" portion of the worksheet and in the last section of this guide).

result OP number 1 coordinate entered, -20. displayed on the calculator.

* * * * * * * * * * *

action Using the procedures outlined in the two (2) previous "actions", enter the remaining four (4) OP azimuths and coordinates.

result All initial azimuths and coordinates are entered and a zero (0) will appear on the calculator display.

B. Later data input. After initial data input to the system, the OP coordinates will be relatively stable. Changes will encompass azimuth refinements, new target acquisition azimuths, and possibly an occasional OP coordinate change. Use of the system during this phase is covered below.

action Press A .

result -18. displayed on calculator.

* * * * * * * * * * *

action If the register number displayed on the calculator is one that is to be changed, enter the new value, and then press R/S . If there is no azimuth or coordinate to be entered (e.g. no sighting from an OP, or dropping a particular OP during its relocation, etc.), press 1 , then press +/- , and then press R/S . If the current register is not to be changed, simply press

R/S . After the last change has been entered and the R/S pressed, press CLR .

result 0 is displayed on the calculator and all data registers contain new data.

C. Target calculation.

action Press CLR , RCL , ## (where ## is a number between 18 and 27). Check registers 18 through 27 to insure that the coordinates and azimuths were correctly entered.

result The contents of the specified register (## - see the data registers section of this guide for register contents) will be displayed on the calculator. Remember that leading and trailing zeroes (0) will not be printed, so treat a coordinate like 3.7654789 as 03.76547890.

* * * * * * * * * *

action If an error on one or more azimuths or coordinates has occurred, press A . When the display contains the register number of an error, then enter the correct value and press R/S . If the register number is not that of an error, press R/S and move to the next register. Repeat this process until all errors are corrected. After the last error has been corrected and the R/S has been pressed, press CLR . Now go back to the previous action and recheck the registers.

result	All azimuths and coordinates have been entered.

* * * * * * * * * * *

action	Press B (this step may take as long as 5.5 minutes).
result	The calculated target location will be displayed on the calculator (remember that leading and trailing zeroes (0) are not printed, so treat a coordinate like 7.975313 as 07.97531300).

* * * * * * * * * * *

action	Press C .
result	The standard deviation will be displayed on the calculator.

* * * * * * * * * * *

action	To return the calculated target coordinate to the calculator display, press X><T .
result	Calculated target location displayed on the calculator.

D A T A   R E G I S T E R S

This system uses forty (40) of the available data registers on the TI59 calculator. The registers and their contents are listed below:

REGISTER	CONTENTS
00 - 17	working storage
18	azimuth for OP number 1
19	coordinate for OP number 1
20	azimuth for OP number 2
21	coordinate for OP number 2
22	azimuth for OP number 3
23	coordinate for OP number 3
24	azimuth for OP number 4
25	coordinate for OP number 4
26	azimuth for OP number 5
27	coordinate for OP number 5
28	calculated target location using OP 2 & 1
29	calculated target location using OP 3 & 1
30	calculated target location using OP 3 & 2
31	calculated target location using OP 4 & 1
32	calculated target location using OP 4 & 2
33	calculated target location using OP 4 & 3
34	calculated target location using OP 5 & 1
35	calculated target location using OP 5 & 2
36	calculated target location using OP 5 & 3

37 calculated target location using OP 5 & 4

38 standard deviation of calculated target location

39 calculated target location

Chapter 5

TI59 TARGET LOCATOR SYSTEM PROGRAM DESCRIPTION

INTRODUCTION

The TI59 Target Locator System is designed to provide an inexpensive, responsive solution to a target locating problem where there are known observation points and azimuths to a target from these points. The program developed to solve this problem is described in the paragraphs below.

PROGRAMMING ASSUMPTIONS

This system deals with true-north azimuths. There will be at least two (2) but not more than five (5) observation points (OP) with azimuths used in the calculations performed by this system. All OP's and targets will be located through the use of an eight (8) digit coordinate defined as shown below:

AB.CCCCDDDD

A = East-west 100,000-meter square identification number

B = North-south 100,000-meter square identification number

CCCC = East-west portion of the eight (8) digit coordinate

DDDD = North-south portion of the eight (8) digit coordinate

P R O G R A M   F L O W

The program first accepts the available OP coordinates and their azimuths to the target. Using them two (2) at a time, the program calculates from one (1) to ten (10) target locations, depending on the actual number of coordinates with azimuths available. This number can be obtained by calculating the combination of the number of OP's with azimuths taken two (2) at a time (i.e. number = (m!) / (n!(m-n)!) where m = number of OP's with azimuths; n = 2; and ! means factorial, e.g. 3! = 3*2*1 = 6). These individual target locations are then averaged to form an approximate target location and a standard deviation based on the individual target locations is calculated. These calculations are discussed in detail below.

This system utilizes true-north azimuths. Although standard trigonometry deals with a normal mathematical coordinate system (i.e., 0 degrees true-north equals 90 degrees mathematic and 180 degrees true-north equals -90 degrees mathematic), the program uses true-north azimuths and only deals with the mathematical coordinate system internally. As each calculation is performed, the azimuths for the two (2) OP's being used are checked to insure that their azimuths are at least one (1) degree apart and that their difference is not greater

than 179 degrees and less than 181 degrees. The Texas Instruments (TI) subroutine used to actually calculate the target location will cause the the calculator to yield an invalid result if 90 or 270 degrees is used. This problem is caused because their use requires the subroutine to divide a number by zero (0), which of course is an undefined mathematical operation. The program avoids this problem by checking each azimuth and if 90 or 270 degrees is found, they are changed to 90.00000001 and 270.0000001 respectively. These altered values do not significantly impact on the calculated results because of the very small difference involved.

The eight (8) digit coordinates discussed above are broken out into north-south and east-west coordinates by the program prior to actual calculations being performed. Calculated coordinates are checked to insure that they will fall within the 100,000-meter identification letters being used during that calculation. Violations will be normalized to the minimum or maximum allowable coordinate value. For example, possible results could be coordinates like 89.12349999 or 80.12340000 if the north-south calculated value falls outside of the area of operations being used; therefore, it is important to insure that the area of operation is completely contained within the 1000 KM square defined by the south-west 100,000-meter square selected for the current set of calculations.

The actual equations used by the TI supplied subroutine are described below.

$$NT = \frac{(E1 - N1 \tan AZ1) - (E2 - N2 \tan AZ2)}{\tan AZ2 - \tan AZ1}$$

$$ET = E1 + (NT - N1) \tan AZ1$$

where

NT = north-south coordinate of the target

ET = east-west coordinate of the target

N1 = north-south coordinate of the first OP

E1 = east-west coordinate of the first OP

N2 = north-south coordinate of the second OP

E2 = east-west coordinate of the second OP

AZ1 = azimuth from first OP to the target

AZ2 = azimuth from the second OP to the target

MAP HANDLING

The program deals with a 1000-KM square that completely encompasses the expected area of operations (A/O). It is important that this 1000-KM square actually contain any area that could possibly fall into consideration. Failure to do so will result in erroneous coordinates being calculated because the program will normalize coordinates that

fall out of the A/O to a point that is in the A/O. One way to deal with this feature is to select an A/O that places the actual target area near the center. This will provide a sufficiently large area to accomodate even relatively large errors in azimuths from the observation posts.

Since the calculator is only capable of processing numeric data, the 100,000-Meter square identification letters must be converted into numbers. This procedure is explained in detail in the User's Guide and will be used to convert letters to numbers at the start and numbers back into letters after the calculations have been performed.

INPUT/OUTPUT DATA

Due to program storage limitations of the TI59 programmable calculator there is no editing of the input data by the program. The function of checking all input data has been assumed by manual procedures which require the program user to verify the accuracy and correctness prior to allowing the program to begin its calculations. The User's Guide explains those procedures in detail.

The program assumes that all azimuths fall between 0.00 and 360.00 degrees. If azimuths requiring less than one degree of accuracy are desired then decimal fractions, not minutes and seconds, will be used. Any level of decimal fractions can be used as long as the azimuth does not contain more than ten digits overall.

Coordinates used by the program fall between 00.00000000

and 99.99999999. Leading and trailing zeroes (0) may be optionally used during data input but will be supressed by the calculator during output.

Throughout the system minus one (-1) is used to denote either a coordinate or azimuth that does not have a current value. The minus one (-1) shows coordinates and azimuths that do not have current valid values, intermediate target locations that were not calculated due to missing OP's or current azimuths, and also the standard deviation when there was only one (1) intermediate target location calculated.

P R O G R A M M I N G   T E C H N I Q U E S

The program was designed in a top down modular manner with the modules being formed by a functional decomposition of the next higher level modules. Whenever possible the functional modules were implemented as subroutines. Due to the severe program storage limitations of the TI59 and speed considerations some of the functional modules were placed "in-line" within a functional module that was designed to call it into use. The functional modules and their descriptions are shown in the annex and the "in-line" modules are identified.

All modules were designed to have one entrance and one exit. This has resulted in a few extra program steps but should be more than worth it, if and when maintenance or enhancements arise.

Subroutines, when used, start and end with a parentheses and do not use

the "CLR" or "=" keys. This practice also has cost a few program steps, but has ensured that the subroutines may be called by a module with an ongoing calculation taking place. The results will be returned in such a manner that they can be included in that calculation. The practice of not using the "CLR" and "=" keys ensures that ongoing calculations in the calling module are not terminated inadvertently by a subroutine.

A technique used to reduce program steps was the "INV" & "LOG" sequence of keys rather than entering very large or small numbers. For example, 1,000,000,000 can be entered as "9", "INV", "LOG" for a saving of seven (7) steps or .000000001 can be entered as "9", "+/-", "INV", "LOG" for a saving of six (6) program steps.

This program utilizes the TI solid state software module for surveying. The specific subroutines used are program 01, subroutine "CLR" and program 16, subroutine "E". These subroutines are used to calculate the intermediate target locations and the approximate target location with its standard deviation.

T I 5 9 T a r g e t L o c a t o r S y s t e m

P r o g r a m D e s c r i p t i o n

A N N E X

```
*******                   *******                    *******
*     *                   *     *                    *     *
*  A  *                   *  B  *                    *  C  *
*     *                   *     *                    *     *
*******                   *******                    *******
                             I
                             I
                +------------+------------+
                I            I            I
                V            V            V
            *********    *********    *********
            *       *    *       *    *       *
            *  LOG  *    *  IXI  *    *  INT  *
            *  ($)  *    *       *    *  ($)  *
            *********    *********    *********
                I               I         I  I
                I               I         I  I
    +-----------+-----------+   +-------+-+  +------+
    I           I           I           I           I
    V           V           V           V           V
*********   *********   *********   *********   *********
*       *   *       *   *       *   *       *   *       *
*   CP  *   *  COS  *   *  STF  *   *  DEG  *   *  STF  *
*       *   *       *   *       *   *       *   *       *
*********   *********   *********   *********   *********
```

($) = placed "in-line" to increase execution speed and reduce memory usage.

SUBROUTINE	FUNCTION
A	enables the user to input data into the calculator registers that contain the OP coordinates and azimuths.
B	calculates the approximate target location and the standard deviation based on the intermediate target locations.
LOG	calculates up to ten (10) intermediate target locations.
CP	azimuth checked for 90 or 270 degrees and changed to 90.00000001 or 270.0000001 respectively if found.
COS	round off north-south or east-west coordinate to a whole

number within the range of 0 to 99999.

STF	combines a north-south and an east-west coordinate into a standard eight (8) digit coordinate.
IXI	checks azimuths and coordinates to insure that a valid number is present.
DEG	decomposes a standard eight (8) digit coordinate into north-south and east-west coordinates.
INT	calculates the approximate target location and its standard deviation.
C	prints registers 18 through 27 on the PC-100A printer, displays the standard deviation on the calculator, and places the approximate target location in the calculator's T register.

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USAWC MILITARY STUDIES PROGRAM

SUPPLEMENT

TO

THE HANDHELD PROGRAMMABLE CALCULATOR: AN INTERIM SOLUTION TO DIRECTION FINDING CALCULATIONS IN THE FIELD

A DIRECTION FINDING PROGRAM FOR THE COMMODORE PET 2001 COMPUTER

AN INDIVIDUAL STUDY PROJECT

by

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15 March 1979

T A B L E   O F   C O N T E N T S

INTRODUCTION

The interim solution proposed in the base study, utilizing the programmable calculator, was conceived as being the lowest level of sophistication which reasonably accomplished the triangulation calculations in the direction finding process. It was also recognized that the programmable calculator with its low cost, low maintenance, and inherent accuracy was also the maximum acceptable time-consumer since the calculator could only equal the calculation speed of the well trained analyst. Continued examination of possible interim solutions logically led to an examination of the rapidly developing series of micro-computers. These inexpensive, light weight, desktop model computers operate on 110 volt current, as does the TI-59 with its electronic printer, and can solve the triangulation problem 50 to 60 times faster than the calculator.

This supplement provides the results of experimentation adapting the Direction Finding Program for the Texas Instruments Programmable 59 Calculator for use in the Commodore Pet 2001 micro-computer. The adaptation compared the speed of the handheld calculator to the microprocessor and improved operator-computer interaction. The results, as expected, were that a variety of direction finding calculations required from 2 to 5 minutes with the handheld calculator, while the same calculations required only 3 to 5 seconds in the computer. Operator-computer interaction is considered excellent because instructions are simple and displayed on the screen for the operator.

The Commodore PET 2001 micro-computer was chosen for this experiment because it is compact, requires only 110 volts for power, has no air conditioning requirements, is inexpensive ($795 for the 8K Model), and is available at the US Army War College.

An operational concept for utilizing the Commodore PET 2001, or similar type micro-computer, would be to place it at the battalion operations center (Technical Control and Analysis Center) as an analyst aid. At this location, the 110 volt power source is readily available and the capability exists to monitor and task the direction finding operation. In a static situation, the micro-computer could easily be moved to the location of the Platoon Leader in charge of the direction finding operation.

The micro-computer has great application at the battalion level, both in the field and in garrison. The Direction Finding Program uses almost all of the available memory of the PET 2001 with 8K of memory and data cannot be transfered to files or stored for later reference. However, the current state of technology is such that a variety of relatively inexpensive computers are available with four to eight times more memory capacity, and which retain the desirable characteristics for tactical use: small, inexpensive, easy to operate, no unique power source nor air conditioning requirement, and available off the shelf with a variety of peripheral devices for expansion. The micro-computer has great utility in that it can be easily operated without a bulky support system for cooling, moving and maintaining it. The limited memory of the small computer and the imagination of the user would seem to be the major limitations of the system. However these limitations

are rapidly being eliminated as technology and young soldiers and officers, who have known computers all of their lives and are not afraid of them, advance.

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THE HANDHELD PROGRAMMABLE CALCULATOR: AN INTERIM SOLUTION--ETC(U)

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PART 1

U S E R   I N S T R U C T I O N S

EQUIPMENT USED

The Target Locator System has been implemented on the Commodore PET 2001 computer. The computer consists of a MCS 6502 microprocessor, 8000 bytes of memory, cathode ray tube (crt), keyboard, and cassette player. All components are built into one unit which is compact enough to sit on a small desk or table.

POWERING COMPUTER ON AND OFF

The PET 2001 computer requires 110 volts of AC power and can be plugged into any conventional wall plug with proper grounding. Once plugged in, the computer is turned on and off by using the power switch located on the rear of the computer. Refer to the PET 2001 User's Manual for the exact location.

LOADING AND STARTING PROGRAM

There are two ways to load and start the program on the PET 2001. Both

methods require the user to place the cassette tape containing the Target Locator program in the cassette player, rewind it, and then follow the instructions shown below.

A. Preferred "Load & Go" method.

action While depressing the "SHIFT" key, depress the "RUN" key.

result The PET 2001 will print "LOAD", a blank line, and then "PRESS PLAY ON TAPE #1."

* * * * * * * * * *

action Depress the button on the cassette unit labeled "PLAY".

result The computer will print "OK", a blank line, "SEARCHING", "FOUND TARGET", "LOADING", "READY", "RUN", and then the main menu* of the program. The program is now running.

B. Alternate "Load & Go" method.

action Enter "LOAD" and then press the "RETURN" key.

result The PET 2001 will print "PRESS PLAY ON TAPE #1".

* * * * * * * * * *

action Depress the button on the cassette unit labelled "PLAY".

result The computer will print "OK", a blank line, "SEARCHING", "FOUND TARGET", "LOADING", and then "READY".

---

*A menu is a display that shows several user options and then requests a user input.

* * * * * * * * * *

action Enter "RUN" and then depress the "RETURN" key.

result The main menu of the program will be displayed. The program is now running.

USE OF THE PROGRAM

The main menu of the program allows the user to select one of six options. The available options are described below and a sample of the program is in Annex 1.* Throughout the program "-1" has been used to denote "no valid entry". It is used to show that there was no valid entry for an input value, or no value was calculated for calculated values, or no standard deviation because there was only one calculated result.

A. Option 1 - "AZIMUTH INPUT". This option allows the user to input and change azimuths. Selection of this option causes the "AZIMUTHS TO TARGET" display to be shown. This display shows the current azimuths and enables the user to change any or all of the azimuths or to return to the main menu.

B. Option 2 - "COORDINATE INPUT". This option allows the user to input and change coordinates. Initial selection of this option causes the

*The photographs in the Annex are black figures on a white background rather than white on black as the screen actually is. This has been done in order to aid in the reproduction of this document.

"ENTER SOUTH-WEST MAP BOARD" display to be shown. At this time enter the map identifier of the south-west map sheet that designates the south-west corner of an area which is approximately a 25 by 25 map sheet square (A-N, P-Z, in an order selected by the user) that completely encompasses the expected area of operations. After entry, or selection of this option after the first usage, the "OP LOCATION COORDINATE DATA" display will be shown. This display shows the current south-west map board, the current OP location coordinates and enables the user to change the map board, any or all of the coordinates, or to return to the main menu.

C. Option 3 - "TARGET CALCULATION". This option calculates the intermediate target locations, calculates the final target location and displays the final target location coordinate and standard deviation.

D. Option 4 - "DISPLAY INPUT DATA AND INTERMEDIATE TARGET LOCATIONS". This option displays all current input data and the calculated intermediate target location coordinates of the last target calculation.

E. Option 5 - "DISPLAY TARGET LOCATION AND STANDARD DEVIATION". This option displays the calculated target location and its standard deviation.

F. Option 6 - "STOP PROGRAM". This option will stop the execution of the program. If the program is restarted through the use of the "RUN" command, all previously used coordinates and azimuths used by the program will have been lost.

PART 2

P R O G R A M   D E S C R I P T I O N

GENERAL

The program was written in PET BASIC. The primary program design constraint that most heavily impacted on program design was the size of core memory. The small size of core memory available and the inclusion of graphics to aid in the man-machine interaction required extreme program compression. Multiple statements were placed on each line to minimize the number of line numbers used. Also, remarks were used only to denote the start of subroutines. It is recognized that the lack of remarks and the statement compression make the program hard to read and understand, and will make any necessary maintenance hard to perform. Although regrettable, it could not be avoided without sacrificing a major option or some of the man-machine graphics, which was an unacceptable course of action. The major elements of the program are described below and a program listing is provided in Annex 2.

LOCATION COORDINATES

The program uses standard 10 digit coordinates (e.g. AB12345678). The coordinate is broken out into an easting and northing value which is

used within the program. The techniques used to convert a standard coordinate into its component parts and back again is discussed in detail in the "Programming Features" paragraph below.

AZIMUTHS

The program uses true-north azimuths that fall between 0 and 360 degrees. The azimuths of 90 and 270 degrees require the computer to attempt a division by zero. The program deals with this problem by checking for 90 and 270 and if found adds .0001 to them. The user should be aware that although the difference introduced is very small, that the further away the target is, the more impact the difference will have. In most circumstances the difference will be so small that it will not be noticeable.

CALCULATIONS

A. The target locations are calculated through the use of the equations shown below.

$$N = \frac{(E1 - N1 \tan AZ1) - (E2 - N2 \tan AZ2)}{\tan AZ2 - \tan AZ1}$$

$$E = E1 + (N - N1) \tan AZ1$$

where

N = northing of the calculated target location

E = easting of the calculated target location

N1 = northing of the first OP location

E1 = easting of the first OP location

N2 = northing of the second OP location

E2 = easting of the second OP location

AZ1 = azimuth from the first OP to the target

AZ2 = azimuth from the second OP to the target

The final target location is calculated by finding the mean of the intermediate eastings and northings.

B. The standard deviation is calculated by finding the standard deviation of the means for the eastings and northings, squaring them, adding the results together, and then taking the square root of that sum. When there is only one intermediate location coordinate, "-1" is used as a standard deviation to show that there is no valid value.

Annex 1

Sample Program Usage

This example was produced by using the worksheet shown on the next page and using the Target Locator program described in the basic document. The sequence of user input shown is believed to be the best one; however, the program provides sufficient flexibility to permit each user to develop techniques that will best suit him.

SINGLE TARGET
DIRECTION FINDING WORKSHEET
INPUT

MAP LETTERS ←→ NUMBERS CONVERSION

EAST - WEST									
0	1	2	3	4	5	6	7	8	9
S									

NORTH - SOUTH									
0	1	2	3	4	5	6	7	8	9
T									

OP			1	2	3	4	5	6	7	8	9	10	
OP # 1	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 18
	AZMUTH TO TARGET		330	-1									
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 19
	E	B			0	4	0	0	6	1	9	5	
OP # 2	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 20
	AZMUTH TO TARGET		283	283									
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 21
	E	C			7	0	0	5	2	5	9	5	
OP # 3	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 22
	AZMUTH TO TARGET		5	5									
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 23
	D	B			4	0	0	2	0	5	9	8	
OP # 4	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 24
	AZMUTH TO TARGET		347	347									
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 25
	D	B			8	2	0	2	2	7	9	8	
OP # 5	TARGET READING #		1	2	3	4	5	6	7	8	9	10	REG # 26
	AZMUTH TO TARGET		306	306									
	MAP LETTERS		MAP NUMBERS		COORDINATE								REG # 27
	E	B			3	8	0	5	9	1	9	5	

RESULTS FROM CALCULATOR

TARGET READING #	MAP LETTERS		MAP NUMBERS		COORDINATE								STANDARD DEVIATION		
1	D	C			5	2	7	3	5	2	8	4	2	6	0
2															
3															
4															
5															
6															
7															
8															
9															
10															
			REG # 39										REG # 38		

SELECT ONE OF THE BELOW

1 AZIMUTH INPUT

2 COORDINATE INPUT

3 TARGET CALCULATION

4 DISPLAY INPUT DATA AND
INTERMEDIATE TARGET LOCATIONS

5 DISPLAY TARGET LOCATION
AND STANDARD DEVIATION

6 STOP PROGRAM

ENTER NUMBER (1-6) OF SELECTION ? 1

[illegible]

OP #	AZIMUTH
1	-1
2	-1
3	-1
4	-1
5	-1

ENTER 'CHANGE' TO CHANGE AZIMUTHS, OR
'QUIT' TO EXIT THIS OPTION
(CHANGE OR QUIT) ?

[illegible]

OP #	AZIMUTH
1	-1
2	-1
3	-1
4	-1
5	-1

ENTER 'CHANGE' TO CHANGE AZIMUTHS, OR
'QUIT' TO EXIT THIS OPTION
(CHANGE OR QUIT) ? C

[illegible]

AZIMUTH = -1

ENTER [illegible] (E.G. 315),
'OK' FOR NO CHANGE,
'DROP' FOR NO VALID ENTRY, OR
'QUIT' FOR NO FURTHER CHANGES

?

[illegible]

AZIMUTH = $\boxed{-1}$

ENTER [illegible] (E.G. 315),

'[illegible]K' FOR NO CHANGE,

'[illegible]ROP' FOR NO VALID ENTRY, OR

'[illegible]UIT' FOR NO FURTHER CHANGES

? 330

[illegible]

AZIMUTH = $\boxed{330}$

ENTER [illegible] (E.G. 315),

'[illegible]K' FOR NO CHANGE,

'[illegible]ROP' FOR NO VALID ENTRY, OR

'[illegible]UIT' FOR NO FURTHER CHANGES

?

[redacted]

AZIMUTH = 330

ENTER [redacted] (E.G. 315),

'[redacted]K' FOR NO CHANGE,

'[redacted]ROP' FOR NO VALID ENTRY, OR

'[redacted]UIT' FOR NO FURTHER CHANGES

? Q

[redacted]

AZIMUTH = -1

ENTER [redacted] (E.G. 315),

'[redacted]K' FOR NO CHANGE,

'[redacted]ROP' FOR NO VALID ENTRY, OR

'[redacted]UIT' FOR NO FURTHER CHANGES

?

.

.

.

Continue until all azimuths have been entered.

[illegible]

OP #	AZIMUTH
1	330
2	283
3	5
4	347
5	306

ENTER '■HANGE' TO CHANGE AZIMUTHS, OR
'■UIT' TO EXIT THIS OPTION
(■HANGE OR ■UIT) ?

[illegible]

OP #	AZIMUTH
1	330
2	283
3	5
4	347
5	306

ENTER 'CHANGE' TO CHANGE AZIMUTHS, OR
'QUIT' TO EXIT THIS OPTION
(CHANGE OR QUIT) ? Q

SELECT ONE OF THE BELOW

1 AZIMUTH INPUT
2 COORDINATE INPUT
3 TARGET CALCULATION
4 DISPLAY INPUT DATA AND INTERMEDIATE TARGET LOCATIONS
5 DISPLAY TARGET LOCATION AND STANDARD DEVIATION
6 STOP PROGRAM

ENTER NUMBER (1-6) OF SELECTION ? 2

```
ENTER SOUTH-WEST
MAP BOARD (E.G. [redacted]) ? ST
```

[redacted]

```
SOUTH-WESTERN MAP BOARD = ST
     OP #              LOCATION COORDINATE
      1                          -1
      2                          -1
      3                          -1
      4                          -1
      5                          -1
ENTER 'CHANGE' TO CHANGE COORDINATES,
      'QUIT' TO EXIT THIS OPTION, OR
      'MAP' TO CHANGE S-W MAP BOARD
      (CHANGE, QUIT, OR MAP) ?
```

[redacted]

SOUTH-WESTERN MAP BOARD = ST

OP #	LOCATION COORDINATE
1	-1
2	-1
3	-1
4	-1
5	-1

ENTER '[redacted]HANGE' TO CHANGE COORDINATES,
'[redacted]UIT' TO EXIT THIS OPTION, OR
'[redacted]AP' TO CHANGE S-W MAP BOARD
([redacted]HANGE, [redacted]UIT, OR [redacted]AP) ? C

[redacted]

LOCATION COORDINATE = -1

ENTER NEW [redacted] (E.G. AB12345678),
'[redacted]K' FOR NO CHANGE,
'[redacted]ROP' FOR NO VALID ENTRY, OR
'[redacted]UIT' FOR NO FURTHER CHANGES
([redacted], [redacted]K, [redacted]ROP, OR [redacted]UIT).

?

[redacted]

LOCATION COORDINATE = -1

ENTER NEW [redacted] (E.G. AB12345678),
'[redacted]K' FOR NO CHANGE,
'[redacted]ROP' FOR NO VALID ENTRY, OR
'[redacted]UIT' FOR NO FURTHER CHANGES
([redacted], [redacted]K, [redacted]ROP, OR [redacted]UIT).

? EB04006195

[redacted]

LOCATION COORDINATE = EB04006195

ENTER NEW [redacted] (E.G. AB12345678),
'[redacted]K' FOR NO CHANGE,
'[redacted]ROP' FOR NO VALID ENTRY, OR
'[redacted]UIT' FOR NO FURTHER CHANGES
([redacted], [redacted]K, [redacted]ROP, OR [redacted]UIT).

? Q

[redacted]

LOCATION COORDINATE = -1

ENTER NEW [redacted] (E.G. AB12345678),

'[redacted]K' FOR NO CHANGE,

'[redacted]ROP' FOR NO VALID ENTRY, OR

'[redacted]UIT' FOR NO FURTHER CHANGES

([redacted], [redacted]K, [redacted]ROP, OR [redacted]UIT).

?

.

.

.

Continue until all coordinates have been entered.

SOUTH-WESTERN MAP BOARD = ST

OP #	LOCATION COORDINATE
1	EB04006195
2	EC70052595
3	DB40020598
4	DB82022798
5	EB38059195

ENTER '■HANGE' TO CHANGE COORDINATES,
'■UIT' TO EXIT THIS OPTION, OR
'■AP' TO CHANGE S-W MAP BOARD
(■HANGE, ■UIT, OR ■AP) ? ■

SOUTH-WESTERN MAP BOARD = ST

OP #	LOCATION COORDINATE
1	EB04006195
2	EC70052595
3	DB40020598
4	DB82022798
5	EB38059195

ENTER '■HANGE' TO CHANGE COORDINATES,
'■UIT' TO EXIT THIS OPTION, OR
'■AP' TO CHANGE S-W MAP BOARD
(■HANGE, ■UIT, OR ■AP) ? ■

```
SELECT ONE OF THE BELOW

     1 AZIMUTH INPUT
     2 COORDINATE INPUT
     3 TARGET CALCULATION
     4 DISPLAY INPUT DATA AND
          INTERMEDIATE TARGET LOCATIONS
     5 DISPLAY TARGET LOCATION
          AND STANDARD DEVIATION
     6 STOP PROGRAM

ENTER NUMBER ( 1-6 ) OF SELECTION ? 3



          WORKING
             .
             .
             .
             .
             .
             .
             .
             .
             .
             .
```

THE CALCULATED TARGET LOCATION
COORDINATE IS

DC52735284

THE STANDARD DEVIATION IS

260

ENTER '[illegible]' TO CONTINUE ? GO

SELECT ONE OF THE BELOW

[illegible] AZIMUTH INPUT

[illegible] COORDINATE INPUT

[illegible] TARGET CALCULATION

[illegible] DISPLAY INPUT DATA AND
INTERMEDIATE TARGET LOCATIONS

[illegible] DISPLAY TARGET LOCATION
AND STANDARD DEVIATION

[illegible] STOP PROGRAM

ENTER NUMBER ([illegible]-[illegible]) OF SELECTION ? 4

9
10

REG # 39

REG # 38

13

* * [redacted] * *

OP #	LOCATION COORDINATE	AZIMUTH
1	EB04006195	330
2	EC70052595	283
3	DB40020598	5
4	DB82022798	347
5	EB38059195	306

* * [redacted] * *

OP #	OP #	LOCATION COORDINATE
1	2	DC51215339
1	3	DC52695082
1	4	DC54314802
1	5	DC49565624
2	3	DC52885300
2	4	DC53175293
2	5	DC54555261
3	4	DC52965386
3	5	DC52955378
4	5	DC52985376

ENTER '[redacted]' TO CONTINUE [redacted]

SELECT ONE OF THE BELOW

[redacted] AZIMUTH INPUT

[redacted] COORDINATE INPUT

[redacted] TARGET CALCULATION

[redacted] DISPLAY INPUT DATA AND
INTERMEDIATE TARGET LOCATIONS

[redacted] DISPLAY TARGET LOCATION
AND STANDARD DEVIATION

[redacted] STOP PROGRAM

ENTER NUMBER ([redacted]) OF SELECTION [redacted]

([redacted]HANGE OR [redacted]UIT) ?

14

[redacted]

OP #	AZIMUTH
1	330
2	283
3	5
4	347
5	306

ENTER '[redacted]HANGE' TO CHANGE AZIMUTHS, OR
'[redacted]UIT' TO EXIT THIS OPTION
([redacted]HANGE OR [redacted]UIT) ? C

[redacted]

AZIMUTH = 330

ENTER [redacted] (E.G. 315),
'[redacted]K' FOR NO CHANGE,
'[redacted]ROP' FOR NO VALID ENTRY, OR
'[redacted]UIT' FOR NO FURTHER CHANGES

? D

[illegible]

AZIMUTH = -1

ENTER [illegible] (E.G. 315),
'[illegible]K' FOR NO CHANGE,
'[illegible]ROP' FOR NO VALID ENTRY, OR
'[illegible]UIT' FOR NO FURTHER CHANGES

? Q

[illegible]

OP #	AZIMUTH
1	-1
2	283
3	5
4	347
5	306

ENTER '[illegible]HANGE' TO CHANGE AZIMUTHS, OR
'[illegible]UIT' TO EXIT THIS OPTION
([illegible]HANGE OR [illegible]UIT) ?

[illegible]

OP #	AZIMUTH
1	-1
2	283
3	5
4	347
5	306

ENTER 'CHANGE' TO CHANGE AZIMUTHS, OR
'QUIT' TO EXIT THIS OPTION
(CHANGE OR QUIT) ? Q

SELECT ONE OF THE BELOW

1 AZIMUTH INPUT
2 COORDINATE INPUT
3 TARGET CALCULATION
4 DISPLAY INPUT DATA AND
INTERMEDIATE TARGET LOCATIONS
5 DISPLAY TARGET LOCATION
AND STANDARD DEVIATION
6 STOP PROGRAM

ENTER NUMBER (1-6) OF SELECTION ?

[redacted]

SOUTH-WESTERN MAP BOARD = ST

OP #	LOCATION COORDINATE
1	EB04006195
2	EC70052595
3	DB40020598
4	DB82022798
5	EB38059195

ENTER '[redacted]HANGE' TO CHANGE COORDINATES,
'[redacted]UIT' TO EXIT THIS OPTION, OR
'[redacted]AP' TO CHANGE S-W MAP BOARD
([redacted]HANGE, [redacted]UIT, OR [redacted]AP) ? C

[redacted]

LOCATION COORDINATE = EB04006195

ENTER NEW [redacted] (E.G. AB12345678),
'[redacted]K' FOR NO CHANGE,
'[redacted]ROP' FOR NO VALID ENTRY, OR
'[redacted]UIT' FOR NO FURTHER CHANGES
([redacted], [redacted]K, [redacted]ROP, OR [redacted]UIT).

?

[redacted]

LOCATION COORDINATE = EB04006195

ENTER NEW [redacted] (E.G. AB12345678),
'[redacted]K' FOR NO CHANGE,
'[redacted]ROP' FOR NO VALID ENTRY, OR
'[redacted]UIT' FOR NO FURTHER CHANGES
([redacted], [redacted]K, [redacted]ROP, OR [redacted]UIT).

? D

[redacted]

LOCATION COORDINATE = -1

ENTER NEW [redacted] (E.G. AB12345678),
'[redacted]K' FOR NO CHANGE,
'[redacted]ROP' FOR NO VALID ENTRY, OR
'[redacted]UIT' FOR NO FURTHER CHANGES
([redacted], [redacted]K, [redacted]ROP, OR [redacted]UIT).

? Q

[redacted]

SOUTH-WESTERN MAP BOARD = ST

OP #	LOCATION COORDINATE
1	-1
2	EC70052595
3	DB40020598
4	DB82022798
5	EB38059195

ENTER '█HANGE' TO CHANGE COORDINATES,
'█UIT' TO EXIT THIS OPTION, OR
'█AP' TO CHANGE S-W MAP BOARD
(█HANGE, █UIT, OR █AP) ?

A MAP BOARD CHANGE WILL CAUSE ALL
INPUT DATA TO BE RE-INITIALIZED!

DO YOU WANT TO RE-SET
THE SOUTH-WEST MAP BOARD?(█/█) ?

A MAP BOARD CHANGE WILL CAUSE ALL
INPUT DATA TO BE RE-INITIALIZED!

DO YOU WANT TO RE-SET
THE SOUTH-WEST MAP BOARD?([illegible]/[illegible]) ? Y

ENTER SOUTH-WEST

MAP BOARD (E.G. [illegible]) ?

ENTER SOUTH-WEST

MAP BOARD (E.G. [redacted]) ? VR

ENTER SOUTH-WEST

MAP BOARD (E.G. [illegible]) ? VW

Annex 2

Program Listing

```
 10 O1=0:O2=0:T9=10000
 20 FORI=1TO10:T1(I)=-1:T2(I)=-1:NEXT
 30 FORI=1TO5:Z(I)=-1:N(I)=-1:E(I)=-1:NE
XT:T1=-1:T2=-1:S=-1
 50 PRINT"███SELECT ONE OF THE BELOW":P
RINT"██    █1█ AZIMUTH INPUT"
 70 PRINT"█    █2█ COORDINATE INPUT":PRIN
T"█    █3█ TARGET CALCULATION"
 90 PRINT"█    █4█ DISPLAY INPUT DATA AND
"
 91 PRINT"          INTERMEDIATE TARGET LOC
ATIONS"
 95 PRINT"█    █5█ DISPLAY TARGET LOCATIO
N":PRINT"          AND STANDARD DEVIATION"
 100 PRINT"█    █6█ STOP PROGRAM"
 110 X$="██ENTER NUMBER ( █1█-█6█ ) OF S
ELECTION ":X1=4:Y1=1:GOSUB8000:PRINTX$
 117 INPUT"████████████████████████████
██████████";X$:A=VAL(X$):IFA<1ORA>6GOTO50
```

```
 500 REM CALC SUBP
 501 PRINT"████████████████████WORKING":K=0:
DEFFNT(Z)=TAN(Z*π/180)
 510 FORI=1TO10:T1(I)=-1:T2(I)=-1:NEXT
 520 FORI=1TO4:FORJ=I+1TO5:K=K+1:PRINT"█
████████████████."
 570 IFZ(I)<0ORN(I)<0GOTO660
 580 IFZ(J)<0ORN(J)<0GOTO660
 585 X1=ABS(Z(I)-Z(J)):IFX1<1GOTO660
 587 IFX1>179ANDX1<181GOTO660
 590 Y1=Z(I):Y2=Z(J):IFY1=90ORY1=270THEN
Y1=Y1+.001
 593 IFY2=90ORY2=270THENY2=Y2+.001
 600 Y1=FNT(Y1):Y2=FNT(Y2):X1=E(I)-N(I)*
Y1:X2=E(J)-N(J)*Y2
 620 T1(K)=(X1-X2)/(Y2-Y1)
 630 T2(K)=INT(E(I)+(T1(K)-N(I))*Y1+.5):
T1(K)=INT(T1(K)+.5)
 660 NEXT
 670 NEXT
```

```
140 ONAGOTO150,170,190,210,230,63999
150 GOSUB3500:GOTO50
170 GOSUB4500:GOTO50
190 GOSUB500:GOTO50
210 GOSUB1500:GOTO50
230 GOSUB2500:GOTO50
```

```
 740 T1=0:T2=0:A=0:B=0:X1=0:D=0:E=0
 760 FORK=1TO10:IFT1(K)<0GOTO800
 770 X1=X1+1:A=A+T1(K):B=B+T2(K):D=D+T1(
K)↑2:E=E+T2(K)↑2
 800 NEXT
 805  IFX1<1THENPRINT"[redacted]INSUFFICIENT
DATA[redacted]":GOSUB8500:RETURN
 820  T1=INT((A/X1)+.5):T2=INT((B/X1)+.5)
:S=-1:IFX1<2GOTO870
 840 X2=ABS(((D-(A↑2/X1))/(X1-1)))↑.5:X3
=ABS(((E-(B↑2/X1))/(X1-1)))↑.5
 860 S=INT((X2↑2+X3↑2)↑.5+.5)
 870 GOSUB2500:RETURN
```

```
1500 PRINT"";TAB(10);"* * INPUT VALUES * *"
1505 PRINT"  OP #";TAB(9);"LOCATION COORDINATE";TAB(30);"AZIMUTH"
1511 FORI=1TO5:E1=E(I):N1=N(I):A1=Z(I):GOSUB6000:GOSUB7000:GOSUB6500
1520 PRINTTAB(2);I;TAB(13);M1$;C8$;TAB(32);A$:NEXT
1535 PRINT" * * INTERMEDIATE TARGET LOCATIONS * *"
1540 PRINT"    OP #";TAB(10);"OP #";TAB(16);"LOCATION COORDINATE"
1560 K=0:FORI=1TO4:FORJ=I+1TO5:K=K+1:E1=T2(K):N1=T1(K):GOSUB6000:GOSUB7000
1575 PRINTTAB(4);I;TAB(10);J;TAB(20);M1$;C8$:NEXTJ,I:PRINT"":GOSUB8500:RETURN
```

```
2500 REM DISPLAY ANSWER
2510 E1=T2:N1=T1:GOSUB6000:GOSUB7000:PRINT"THE CALCULATED TARGET LOCATION"
2535 PRINT"    COORDINATE IS":X$=""
2550 X1=12:Y1=3:GOSUB8000:PRINTX$:PRINT"O";M1$;C8$
2570 PRINT"THE STANDARD DEVIATION IS":X$=""
2585 X1=LEN(STR$(S))+3:Y1=3:GOSUB8000:PRINTX$:PRINT"O";S
2610 PRINT"":GOSUB8500:RETURN
```

```
 3000 REM AZ CHANGE OPTION
 3005 FORI=1TO5
 3010 PRINT"■■■■OP #";I;"■":PRINT"■■■■
OP #";I;"■":X$="■AZIMUTH = "
 3022 X1=LEN(STR$(Z(I)))+3:Y1=3:GOSUB800
0:PRINTX$:PRINT"■■■■■■■■■■■■■■■■[O]";Z(I)
 3030 PRINT"■■■ENTER ■AZIMUTH■ (E.G. 315
),":PRINT"■        '■O■K' FOR NO CHANGE,"
 3032 PRINT"■        '■D■ROP' FOR NO VALID
 ENTRY, OR"
 3033 PRINT"■        '■Q■UIT' FOR NO FURTH
ER CHANGES"
 3034 X$="■      ( ■0■-■360■, ■O■K, ■D■R
OP, OR ■Q■UIT ).":X$="■■■■■■■■"
 3036 X1=7:Y1=1:GOSUB8000:PRINTX$:INPUT"
■■■■■■■■■";X$
 3040 IFLEFT$(X$,1)="D"THENZ(I)=-1:GOTO3
010
 3045 IFLEFT$(X$,1)="Q"THENRETURN
 3050 IFLEFT$(X$,1)="0"THENZ(I)=0:GOTO30
10

 3055 IFVAL(X$)>.0000001ANDVAL(X$)<=360T
HENZ(I)=VAL(X$):GOTO3010
 3056 IFABS(VAL(X$))>0GOTO3010
 3160 NEXT:RETURN
```

```
3500 REM AZ ENTRY ROUTINE
 3505 PRINT"AZIMUTHS TO TARGET":PRIN
T"";TAB(5);"OP #";TAB(20);"AZIMUTH"
 3520 FORI=1TO5:A1=Z(I):GOSUB6500:PRINT"
";TAB(5);I;TAB(22);A$:NEXT
 3550 PRINT"ENTER 'CHANGE' TO CHANGE
AZIMUTHS, OR"
 3560 PRINT"        'QUIT' TO EXIT THIS
OPTION"
 3570 X$="        ( CHANGE OR QUIT )
":X1=9:Y1=1:GOSUB8000:PRINTX$
 3573 INPUT"";
X$:IFLEFT$(X$,1)<>"C"THENRETURN
 3590 GOSUB3000:GOTO3500
```

```
 4000 REM OP CHANGE OPTION
 4005 FORI=1TO5
 4010 PRINT""
 4015 PRINT"OP #";I;"":E1=E(I):N1=N(I)
:GOSUB6000:GOSUB7000
 4040 X$="LOCATION COORDINATE = ":X1=
12:Y1=3:GOSUB8000:PRINTX$
 4046 PRINT"O";M
1$;C8$
 4050 PRINT"ENTER NEW COORDINATE (E
.G. AB12345678),"
 4060 PRINT"        'OK' FOR NO CHANGE,
"
 4070 PRINT"        'DROP' FOR NO VALID
ENTRY, OR"
 4080 PRINT"        'QUIT' FOR NO FURTH
ER CHANGES"
 4090 PRINT"        ( COORDINATE, OK,
DROP, OR QUIT ).":X$="
"4092 X1=13:Y1=1:GOSUB8000:PRINTX$:INPUT
"";X$
 4100 IFVAL(RIGHT$(X$,10))>0GOTO4170
```

```
4110 X$=LEFT$(X$,1):IFX$="D"THENE(I)=-1:N(I)=-1:GOTO4010
4130 IFX$="Q"THENRETURN
4140 GOTO4300
4170 M1$=MID$(X$,1,2):X1=VAL(MID$(X$,3,8)):IFX1>=0ANDX1<=99999999GOTO4230
4210 PRINT"■■■ENTER VALUE BETWEEN 0 AND 99999999":GOTO4015
4230 E(I)=INT(X1/T9):N(I)=INT((X1/T9-INT(X1/T9))*T9+.5):A=ASC(MID$(M1$,1,1))
4254 IFA>90ORA<65THENE(I)=-1:N(I)=-1:PRINT"■■■BAD MAP ID":GOTO4015
4260 IFA>=79THENA=A-1
4265 IFA<O1THENA=A+25
4270 B=ASC(MID$(M1$,2,1))
4274 IFB>90ORB<65THENE(I)=-1:N(I)=-1:PRINT"■■■BAD MAP ID":GOTO4015
4280 IFB>=79THENB=B-1
4285 IFB<O2THENB=B+25
4290 E(I)=A*T9+E(I):N(I)=B*T9+N(I):GOTO4010
4300 NEXT:RETURN


4500 REM COORD ENTRY ROUTINE
4504 IFO1<1THENGOSUB7560
4510 PRINT"■■OP LOCATION COORDINATE DATA■":X1=O1:IFX1>=79THENX1=X1+1
4514 X2=O2:IFX2>=79THENX2=X2+1
4520 PRINT"■SOUTH-WESTERN MAP BOARD = ";CHR$(X1);CHR$(X2)
4530 PRINT"■";TAB(5);"OP #";TAB(20);"LOCATION COORDINATE"
4540 FORI=1TO5:E1=E(I):N1=N(I):GOSUB6000:GOSUB7000
4560 PRINT"■";TAB(5);I;TAB(24);M1$;C8$:NEXT
4570 PRINT"■ENTER '■C■HANGE' TO CHANGE COORDINATES,"
4580 PRINT"■       '■Q■UIT' TO EXIT THIS OPTION, OR"
4590 PRINT"■       '■M■AP' TO CHANGE S-W MAP BOARD"
4600 X$="■       (■C■HANGE, ■Q■UIT, OR ■M■AP)":X1=9:Y1=1:GOSUB8000:PRINTX$
```

```
 4606 INPUT"[redacted]";A$:A$=LEFT$(A$,1)
 4620 IFA$="C"THENGOSUB4000:GOTO4500
 4630 IFA$="M"THENGOSUB7500:ONAGOTO20,45
00
 4660 RETURN
```

```
 6000 REM COORD OUT - USING E1,N1,C8$
 6005 C8$="":IFE1=-1THENC8$="        -1":R
ETURN
 6030 X1=INT((E1/T9-INT(E1/T9))*T9+.5)*T
9:X2=INT((N1/T9-INT(N1/T9))*T9+.5)
 6060 X$=STR$(X1+X2):A=LEN(X$)-1:FORD=1T
OA:B=A+2-D
 6090 C8$=MID$(X$,B,1)+C8$:NEXT:IFA>=8TH
ENRETURN
 6110 FORB=1TO8-A:C8$="0"+C8$:NEXT:RETUR
N
```

```
6500 REM AZ OUT CALC USING A1 & A$
6504 IFA1<0THENA$=" -1":RETURN
6505 A$="":X$=STR$(A1):A=LEN(X$)-1:FORD
=1TOA:B=A+2-D
6550 A$=MID$(X$,B,1)+A$:NEXT
6560 IFA>=3THENRETURN
6570 FORB=1TO3-A:A$=" "+A$:NEXT:RETURN
```

```
7000 REM MAP ID CALC USING E1, N1, M1$
7010 M1$="  ":IFE1<0THENRETURN
7015 IFE1<0THENRETURN
7020 A=INT(E1/T9):B=INT(N1/T9)
7030 REM NORMALIZE A & B
7040 IFA<65THENA=25+A:GOTO7030
7060 IFA>89THENA=A-25:GOTO7030
7080 IFB<65THENB=25+B:GOTO7030
7100 IFB>89THENB=B-25:GOTO7030
7110 IFA>=79THENA=A+1
7120 IFB>=79THENB=B+1
7130 M1$=CHR$(A)+CHR$(B):RETURN
```

```
7500 REM S-W MAP BOARD CHANGE
7510 PRINT"A MAP BOARD CHANGE WILL CAUSE ALL"
7520 PRINT"INPUT DATA TO BE RE-INITIALIZED!"
7530 PRINT"DO YOU WANT TO RE-SET":X$="THE SOUTH-WEST MAP BOARD?(Y/N)"
7540 X1=4:Y1=1:GOSUB8000:PRINTX$
7550 INPUT"";X$:IFLEFT$(X$,1)<>"Y"THENA=2:RETURN
7560 REM ACCEPT NEW MAP ID
7570 PRINT"ENTER SOUTH-WEST"
7580 X$="MAP BOARD (E.G. AB)":X1=5:Y1=1:GOSUB8000:PRINTX$
7600 INPUT"";X$
7605 IFLEN(X$)<2THEN:PRINT"BAD INPUT - TRY AGAIN":GOTO7580
7610 O1=ASC(LEFT$(X$,1)):O2=ASC(MID$(X$,2,1))
7620 IFO1<65ORO1>90THENPRINT"BAD INPUT - TRY AGAIN":GOTO7580
7630 IFO2<65ORO2>90THENPRINT"BAD INPUT - TRY AGAIN":GOTO7580
7640 IFO1>=79THENO1=O1-1
7650 IFO2>=79THENO2=O2-1
7660 A=1:RETURN
```

```
8000 REM BOX MAKER-X1,Y1,X$
8010 X$=X$+"█ ":FORA=1TO(Y1+1)/2:X$=X$+
"██ ":NEXT
8030 FORA=1TOX1+1:X$=X$+" ":NEXT:FORA=1
TOY1+1:X$=X$+"██ ":NEXT
8050 FORA=1TOX1+1:X$=X$+"██ ":NEXT
8060 FORA=1TO(Y1+1)/2-1:X$=X$+"██ ":NEX
T:X$=X$+"██ █":RETURN
```

```
8500 REM ENTER GO TO CONT SUBROUTINE
8510 X$="ENTER '█GO█' TO CONTINUE ":X1=
5:Y1=1:GOSUB8000:PRINTX$
8540 INPUT"█████████████████████████";X$
:RETURN
63999 END
```